



# Unmanned Intratheater Airlift

---

Kevin J. McGowan

Major, USAF

Air Command and Staff College

Wright Flyer Paper No. 45



Report Documentation Page			Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.				
1. REPORT DATE <b>DEC 2010</b>	2. REPORT TYPE		3. DATES COVERED <b>00-00-2010 to 00-00-2010</b>	
4. TITLE AND SUBTITLE <b>Unmanned Intratheater Airlift</b>			5a. CONTRACT NUMBER	
			5b. GRANT NUMBER	
			5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)			5d. PROJECT NUMBER	
			5e. TASK NUMBER	
			5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Air University,Air Command and Staff College,Maxwell AFB,AL,36112</b>			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSOR/MONITOR'S ACRONYM(S)	
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution unlimited</b>				
13. SUPPLEMENTARY NOTES				
14. ABSTRACT <b>The movement of supplies and personnel within the Operation Iraqi Freedom and Operation Enduring Freedom areas of operation is currently extremely costly, hazardous and inefficient. Frequent attacks against insecure lines of communication and difficult terrain have led to a constantly increasing tactical airlift requirement. As of September 2009 75 percent of all troop locations in Afghanistan and Iraq required resupply by ground convoy, airdrop, or verticaltakeoff- and-landing aircraft. Unfortunately, the Department of Defense (DOD) currently lacks the capability to fulfill all tactical airlift requests. This paper investigates the DOD's tactical logistical challenges and each service's tactical lift requirements, especially with respect to the movement of supplies from forward supply hubs to forward forces. To address these challenges and requirements, the author suggests the use of remotely piloted aircraft (RPA) as a potential solution. Focusing on existing and quickly emerging technologies as well as the joint operating requirements, the author proposes RPA performance and design characteristics along with a concept of employment that increases tactical lift capabilities and meets all current service requirements.</b>				
15. SUBJECT TERMS				
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>Same as Report (SAR)</b>	18. NUMBER OF PAGES <b>154</b>
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>		

## **Air University**

Lt Gen Allen G. Peck, Commander

## **Air Command and Staff College**

Brig Gen Anthony J. Rock, Commandant

Col Robert J. Smith, PhD, Dean

Lt Col Kyle D. Gresham, PhD, Director of Research

Col Brett E. Morris, PhD

and Maj John L. Mansuy, Series Editors

Budd A. Jones Jr., Essay Advisor

## **Air University Press**

Gen John A. Shaud, USAF, Retired, PhD

Director, Air Force Research Institute

Dr. Richard Bailey, Project Editor

Sandi Davis, Copy Editor

Ann Bailey, Prepress Production

Daniel Armstrong, Cover Design

Please send inquiries or comments to  
Editor

*The Wright Flyer Papers*

Air Command and Staff College (ACSC/DEI)

225 Chennault Circle, Bldg. 1402

Maxwell AFB AL 36112-6426

Tel: (334) 953-6810

Fax: (334) 953-2269

E-mail: ACSC@maxwell.af.mil

AIR UNIVERSITY  
AIR COMMAND AND STAFF COLLEGE



# **Unmanned Intratheater Airlift**

KEVIN J. MCGOWAN  
Major, USAF

Air Command and Staff College  
Wright Flyer Paper No. 45

Air University Press  
Air Force Research Institute  
Maxwell Air Force Base, Alabama

December 2010

This Wright Flyer Paper and others in the series are available electronically at the Air University Research Information Management System website at <http://research.maxwell.af.mil> and the AU Press website at <http://aupress.au.af.mil>.

#### **Disclaimer**

Opinions, conclusions, and recommendations expressed or implied within are solely those of the author and do not necessarily represent the views of Air University, the United States Air Force, the Department of Defense, or any other US government agency. Cleared for public release: distribution unlimited.

# **Contents**

<i>Chapter</i>		<i>Page</i>
	DISCLAIMER . . . . .	ii
	FOREWORD . . . . .	v
	ABSTRACT . . . . .	vii
	ACKNOWLEDGMENTS . . . . .	ix
	EXECUTIVE SUMMARY . . . . .	xi
1	INTRODUCTION . . . . .	1
	Notes . . . . .	12
2	OPERATIONAL REQUIREMENTS . . . . .	15
	Notes . . . . .	26
3	TECHNOLOGY REVIEW/PROOF OF CONCEPT . . . . .	27
	Notes . . . . .	41
4	PROPOSED SOLUTION . . . . .	45
	Notes . . . . .	51
5	SYNOPSIS OF CONCEPT OF EMPLOYMENT . . . . .	53
	Notes . . . . .	59
6	CONCLUSION . . . . .	61
<i>Appendix</i>		
1	Contract Lift Configurations . . . . .	65
2	John Warner National Defense Authorization Act for Fiscal Year 2007 . .	67
3	Service RPA Requirements . . . . .	69
4	Concept of Employment . . . . .	71
	DEFINITIONS . . . . .	119
	ABBREVIATIONS . . . . .	123
	BIBLIOGRAPHY . . . . .	127



## ***Foreword***

It is with great pride that Air Command and Staff College presents another in a series of award-winning student research projects from our academic programs that reach nearly 11,000 students each year. As our series title indicates, we seek to promote the sort of imaginative, forward-looking thinking that inspired the earliest aviation pioneers, and we aim for publication projects which combine these characteristics with the sort of clear presentation that permits even the most technical topics to be readily understood. We sincerely hope what follows will stimulate thinking, invite debate, and further encourage today's air war fighters in their continuing search for new and better ways to perform their missions—now and in the future.

A handwritten signature in black ink, appearing to read 'Anthony J. Rock', written in a cursive style.

ANTHONY J. ROCK  
Brigadier General, USAF  
Commandant





## ***Abstract***

The movement of supplies and personnel within the Operation Iraqi Freedom and Operation Enduring Freedom areas of operation is currently extremely costly, hazardous, and inefficient. Frequent attacks against insecure lines of communication and difficult terrain have led to a constantly increasing tactical airlift requirement. As of September 2009, 75 percent of all troop locations in Afghanistan and Iraq required resupply by ground convoy, airdrop, or vertical-takeoff-and-landing aircraft. Unfortunately, the Department of Defense (DOD) currently lacks the capability to fulfill all tactical airlift requests.

This paper investigates the DOD's tactical logistical challenges and each service's tactical lift requirements, especially with respect to the movement of supplies from forward supply hubs to forward forces. To address these challenges and requirements, the author suggests the use of remotely piloted aircraft (RPA) as a potential solution. Focusing on existing and quickly emerging technologies as well as the joint operating requirements, the author proposes RPA performance and design characteristics along with a concept of employment that increases tactical lift capabilities and meets all current service requirements.



## ***Acknowledgments***

I would like to thank my research advisor, Budd Jones, for his guidance, insight, and assistance in reviewing, editing, and improving this paper. I also thank Donald Anderson, Air Mobility Command (AMC)/A9; Demetrius Glass, US Army/G4; Maj Thomas Heffern, US Marine Corps Unmanned Aircraft Systems Requirements; Maj Robert Hilliard, US Transportation Command/J3-ED; Robert Nagel, AMC/A8XC; Lt Col Travis Burdine, AF/A2U; Mike Melnyk and LT Sidney Cochran III, Naval Safety Center; and LTC David Fleckenstein, US Army Combat Readiness Center, for their insight and assistance in gathering the data used in this study.



## ***Executive Summary***

Recent military engagements have seen a radical shift in adversary tactics. In addition to confronting traditional conventional forces, the US military now faces an increasing use of irregular warfare tactics to offset the US technological and operational advantages. Long, slow, and predictable supply convoys along overstretched lines of communication also tend to place US supplies and troops at significant risk. This is further complicated by a general lack of logistical infrastructure and increasing requirements for US forces to assume positions in isolated and rugged locations.

The low likelihood of these trends changing in future engagements places the DOD in a difficult position. How do you increase cargo movement to isolated forward operating bases (FOB) in relatively inaccessible locations while maintaining secure lines of communication? Operational and budgetary limitations coupled with tooth-to-tail ratio, shrinking force sizes, increasing logistical requirements, and deployment footprint concerns require immediate solutions, even if finding them means searching outside the box. This challenge dictates a movement away from traditional resupply means and an accompanying paradigm and doctrinal shift.

Advancements in technology, increased needs, and shrinking budgets present the DOD with both challenges and opportunities. Augmenting the current tactical airlift system with a modular autonomous and/or semiautonomous unmanned tactical airlift aircraft offers a flexible, responsive, and inexpensive solution that will increase airlift capacity, minimize carbon footprint, reduce risk to ground and airlift crews, and reduce wear and tear on manned assets.

## **The Problem**

The DOD's use of the spoke and hub distribution method has proven itself as an efficient and effective means of supply distribution. However, while the strategic lift portion of the factory-to-foxhole chain is well established and relatively efficient for routine shipments, the "last tactical mile" segment is less than ideal. Depending upon a combination

of fixed-wing, rotor wing, ground transport, host nation, and contract services, the last tactical mile segment of the cargo movement process is inefficient, typically service oriented, and in some cases extremely dangerous. In addition to an assortment of other factors, delivery delays resulting from the current tactical lift system can have a significant operational impact upon fielded forces from both a safety and a combat effectiveness perspective.<sup>1</sup>

In Operations Enduring Freedom (OEF) and Iraqi Freedom (OIF), insurgent and enemy force tactics and limited infrastructures have made the transport of supplies via ground both deadly and slow. These challenges have led to an increased reliance upon a combination of airdrop and airland flights to move supplies and personnel from major hubs directly to their points of need. Aircraft availability, weather, and terrain, however, have caused delayed movement and a requirement to move supplies by alternate means.

In Afghanistan the general lack of passable roads to remote villages, FOBs, and deployed troops makes airlift the only viable option to resupply many locations. In fact, while FOBs have taken advantage of the limited number of runways, only about 24 percent of FOBs can be serviced by C-130 or larger aircraft.<sup>2</sup> This lack of essential airland infrastructure has made vertical takeoff and landing (VTOL) airlift, ground convoy, and airdrop essential pieces of the logistics system in both theaters.<sup>3</sup>

To address these needs and limitations, the Army and Marines rely heavily upon formations of rotor-wing and tilt-rotor airlift assets to transport much-needed supplies and personnel.<sup>4</sup> As most resupply is routine and predictable, regularly scheduled supply routes can be and typically are established. Unfortunately, although these routes tend to be effective, they are inefficient and tend to draw limited airlift assets away from their primary missions. Additionally, they waste fuel and time while exposing the flight crew and passengers to unnecessary risks. Furthermore, the increased utilization rates and harsh environments have also led to increased maintenance requirements and premature aging of the airlift fleet.<sup>5</sup>

Augmenting the military lift assets is an assortment of private and commercial fixed- and rotor-wing contract carriers. While the total quantity of cargo and passengers moved

by these carriers pales in comparison to those lifted by military assets, these carriers provide an essential service. With significant passenger loads and cargo loads ranging from a few hundred pounds (lb.) to over 35,000 lb., these routine flights free up critical airlift assets for other missions and reduce military aircraft utilization.<sup>6</sup> Unfortunately, however, the nature of this service imposes restrictions on the types and quantities of cargo private and commercial carriers can lift, particularly with regard to destinations and sensitive cargo, passengers, and missions.<sup>7</sup> It can also limit mission responsiveness and flexibility.

Augmenting the airland capabilities is the steadily increasing airdrop utilization, capability, and capacity. While this trend will probably continue, thus far conventional airdrop has been unable to keep fielded forces adequately supplied in rugged terrain. Even the joint precision airdrop system and low-cost, low-altitude airdrop systems that are capable of hitting a target area of 50 meters are unable to reliably supply troops in urban environments or rough terrain (such as on a ridgeline or mountainside). Additionally, a forward location's request for supplies takes an average of approximately 72 hours to be answered if the requested supplies are already in theater and several more days if they must be lifted in.<sup>8</sup>

Resupply flights, especially in combat situations, also expose crews and aircraft to a wide assortment of safety hazards. For example, between 11 September 2001 and 14 December 2009, spatial disorientation and brownout and whiteout conditions directly contributed to 10 US Air Force and 55 US Army rotor-wing mishaps in the Iraq and Afghanistan areas of responsibility (AOR) alone. The US Navy experienced an additional five Class A mishaps in the CH-46, HH-60, and UH-1 aircraft between 11 September 2001 and 18 August 2008. Together these mishaps resulted in 49 US Army and 15 Navy/Marine Corps fatalities.<sup>9</sup> Such human factors as "get-home-itis," "mission-itis," fatigue, overconfidence, and standards deviations can also significantly increase the chances of a mishap. Crew duty-day limitations coupled with crew rest location limitations and mission expectations may also place additional pressure, stress, and ultimately risk upon a crew.



Despite the current airlift limitations and costs, the extensive OEF and OIF air bridges have saved countless lives and supplies. The increased utilization of fixed-wing and VTOL assets to support cargo movement needs have “decreas[ed] the need for hazardous ground convoys . . . and saved lives.”<sup>10</sup> The increased airlift has also increased the responsiveness and speed of time-sensitive (TS)/mission-critical (MC) supply delivery. Despite these accomplishments, approximately 80 percent of supplies are still transported by ground convoy.<sup>11</sup>

While ground convoys can carry significantly more cargo than tactical airlift assets, their slow speeds result in convoy personnel being exposed to threats for extended periods along predictable routes. In high-threat environments, extended threat exposure times have direct safety implications upon the personnel involved in the convoys (typically from two to three personnel per vehicle). In fact, from 19 March 2003 to 30 September 2007, improvised explosive devices (IED) killed 1,503 US service members in Iraq alone. Car bombs killed an additional 133. While not all of these fatalities occurred during resupply ground convoys, the fatalities do illustrate the significance of the problem. In fact, car bombs and IEDs were the leading causes of death in Iraq (43 percent) followed by hostile fire (31 percent) during this period.<sup>12</sup> Likewise, in Afghanistan from 2003 through 2009, IEDs accounted for approximately 49 percent of all US fatalities due to hostile action (35 percent of all US fatalities during this period).<sup>13</sup>

## **Requirements**

While an official DOD tactical airlift capability gap and requirements list has not been published at the time of this report, each service has taken steps towards quantifying its respective needs for an unmanned or remotely piloted tactical airlift platform (hereafter referred to as MQ-A). While the identified requirements vary, the four focuses common among the services include (1) increase responsiveness through on-demand airlift for small loads (fewer than 3,000 lb.); (2) remove, or at least reduce, the number of supply trucks on the road; (3) mitigate the impact of shortages in tactical airlift aircraft and aircrew (without significantly in-

creasing carbon footprint); and (4) increase airlift capacity, accuracy, and responsiveness of delivery (without significantly increasing manpower). In all cases, the MQ-A is intended to augment existing manned tactical lift assets, thereby enhancing current lift capabilities, improving safety, and enabling manned assets to focus on other missions such as passenger or large cargo movement.

Considering the joint operating environment, any future tactical lift platform must meet the requirements for each service it is intended to support. After combining each service's unmanned tactical lift requirements, as established to date, a list of joint unmanned intratheater airlift platform capabilities can be developed. Generally, the MQ-A must have an open architecture and be multimission capable, all weather, and net-centric. It must also be capable of carrying standard loads and potentially have an optionally manned capability. Underlying all these attributes is a need to be responsive, flexible, safe, survivable, inexpensive, and reliable.

As for specific capabilities, the MQ-A must be multirole capable, preferably utilizing mission modules, while remaining rugged and reliable with low maintenance requirements. Considering the hostile environments it will be required to operate in, it should be affordable and, given the right conditions, attritable. It must be able to operate under enemy fire; in a chemical, biological, radiological, nuclear, and high-yield explosive or other high-risk environments; and in all weather conditions (to include restricted visibility). It should also be able to avoid most ground threats by cruising at altitudes outside their effective ranges and must be able to defeat most ground threats when operating within their threat envelopes.

The MQ-A should be able to travel at least 500 nautical miles at speeds greater than 250 knots while carrying a payload of up to 3,000 lb.<sup>14</sup> It must be capable of autonomous and semiautonomous operations to include autonomous VTOL in all weather conditions and threat environments. In addition, it should have an internal and/or external load-carrying capability with no external loading equipment required. Considering the current operating environments, it should be small enough to operate in such confined spaces as an urban environment (preferably with a smaller foot-

print than current manned VTOL assets), a small clearing, a mountainside, or a ridgeline at elevations up to 12,000 feet. It must also be easily deployed on board existing strategic lift assets with minimal disassembly.

## **Existing Technologies**

While these requirements may appear excessive and beyond current capabilities, the technology already exists to make the MQ-A a reality. However, some roadblocks do exist. For example, most of the technologies are proprietary, and some are still in development. Based upon the aforementioned requirements, the primary technical concerns involve (1) multifunctionality (i.e., cargo, armed/unarmed intelligence, surveillance, reconnaissance [ISR], etc.), (2) propulsion, (3) fielded-force landing-zone modification, (4) autonomous VTOL, (5) threat avoidance, (6) collision avoidance, (7) autonomous or semiautonomous route creation and modification, (8) automating manned aircraft, and (9) safety, although the latter is more a factor of design than technology.

### **Notes**

(All notes appear here in shortened form. For full details, see the appropriate entry in the bibliography.)

1. Delays can result from such problems as environmental, mechanical, and personnel limitations and enemy action. For example, cargo and/or personnel may remain at a distribution point while they await transportation. Other delays may result from maintenance, crew availability (e.g., qualifications, crew rest, etc.), the lift asset making additional stops en route to the cargo's final destination, or even enemy action at the point of departure, en route, or at the final destination. Weather considerations, especially when considering helicopter operations, can also lead to delayed or even missed deliveries due to weather avoidance considerations (primarily from obscured visibility conditions).

2. As of 12 December 2009, Afghanistan had 16 paved and 35 unpaved runways (less than one-half the number of runways in Iraq). See Central Intelligence Agency, "Afghanistan," *World Factbook*; and Anderson, *OEF, COPs, and Bases.xlsx*. Since 11 September 2001, the average AMC load is approximately 7,500 lb. of cargo and over 10 passengers per flight. See Lichte, *Air Mobility Master Plan: 2010*, 2.

3. VTOL airlift refers to all fixed-wing, rotor-wing, tilt-rotor, and any other platforms capable of conducting a VTOL.

4. Current doctrine calls for rotary-wing assets to fly always in formations of two or more aircraft regardless of the load being transported. This includes flights to move a small number of passengers with small cargo items even if one or more of the aircraft will be empty. While this practice enhances force protection, it is expensive, inefficient, and increases maintenance requirements.

5. Manske, *Unmanned Airlift*, 8; and Vice Chief of Staff Army/Vice Chief of Staff Air Force, *Concept of Employment*, 7.

6. In Afghanistan from January 2009 to June 2009, civilian fixed-wing carriers flew 4,700 sorties (4,686 of which were short takeoff and landing [STOL] flights) as compared to just over 1,600 US military fixed-wing flights (i.e., C-5, C-17, and C-130) with average cargo loads of 1,166 lb. and 14,812 lb., respectively. During this period, civilian rotor-wing aircraft flew 581 missions, with each mission having as many as 27 legs. These VTOL missions transported an average of 3,357 lb. of cargo and 40 passengers per mission. The STOL aircraft averaged six passengers per flight. All together, the civilian STOL and VTOL aircraft transported 51,750 passengers and 7,014,845 lb. of cargo during this period alone. Not including airdrop, special operations forces and Marine Corps missions, military fixed-wing aircraft transported over 24 million lb. of cargo. An additional 6,540,936 lb. of cargo were moved by theater express within Afghanistan from January to May 2009 with an average monthly load of 1,308,187 lb. Unfortunately, as there is currently no central tracking system for cargo moved by rotor-wing aircraft in the tactical environment, the load data for military rotor-wing and tilt-rotor aircraft was unavailable. Per Anderson, YD-03 (assistant director, Analyses, Assessments, and Lessons Learned, AMC/A9), interview by the author, 19 January 2010. For load data, see US Transportation Command military and contract civilian carrier flying-hour and monthly activity spreadsheets (January 2009–June 2009) for flights within Afghanistan. Since 11 September 2001, the average AMC load is approximately 7,500 lb. of cargo and over 10 passengers per flight. See Lichte, *Air Mobility Master Plan: 2010*, 2.

7. Based upon US Transportation Command Flying Hour and Monthly Activity Log spreadsheets and an interview provided by Anderson.

8. Ibid.

9. See Air Force Safety Automated System (AFSAS); Navy Safety Center, *Class A Mishap Data for the Period of 1998–2008*; and Army Combat Readiness/Safety Center, *Class A, B, and C Mishap Data*. Thirty-six of the 55 Army mishaps (resulting in 47 fatalities) involved cargo- and troop-carrying aircraft. The remaining mishaps involved OH-58s and AH-64s.

10. Lichte, "Commander's Intent," 2.

11. Hilliard, US Transportation Command/J3, e-mail to the author, 16 February 2010. Actual quantities of supplies and personnel transported via rotor wing and ground transportation were unavailable due to limitations in the current logistical tracking systems. While US Transportation Command and Air Mobility Command track cargo airlifted via the Air Force lift assets (to include airdrop), once the cargo is offloaded and transferred to the Army and Marine Corps at a forward supply location (e.g., Kandahar, Bagram, Baghdad, etc.), the cargo is considered "delivered to destination." The "last tactical mile" movement of the supplies by rotor

wing and ground transportation from this supply depot to other FOBs is tracked and kept by the individual units performing the supply movement (e.g., each combat air brigade maintains its own records). The lack of a central unifying database has made it virtually impossible to obtain reliable theaterwide intratheater cargo movement data. Without this data, an accurate comparison between quantities moved by airdrop, rotor wing, tilt rotor, and ground transport could not be made.

12. O'Hanlon and Campbell, *Iraq Index*, 18.

13. iCasualties.org, "Operation Enduring Freedom."

14. Per US Transportation Command Flying Hour and Monthly Activity Log spreadsheets; and Anderson, interview. In Afghanistan from January to June 2009, civilian VTOL aircraft transported an average of 3,357 lb. of cargo per mission. Military VTOL cargo lift statistics were unavailable.

# Chapter 1

## Introduction

*In view of the information GAO [General Accounting Office] developed and DOD's position, the Congress should scrutinize proposed manned aircraft developments to assure that the DOD gives adequate consideration to the use of the remotely piloted vehicle technology for some missions. While DOD is making some use of the technology, there is a need to assure that its use is maximized where suited to save lives and money.*

—General Accounting Office, 1981  
(now General Accountability Office)

Remotely piloted aircraft (RPA) have been a reality of the modern battlefield since 1916 when Archibald Montgomery Low's team invented the Aerial Target (AT) for the Royal Flying Corps.<sup>1</sup> The AT later evolved into the first remotely piloted aircraft (the Ruston Proctor AT in 1917) to be used as a guided bomb. Low's Royal Flying Corps Experimental Works developed the first guided rockets later that same year.<sup>2</sup> Drawing on research and early RPAs flown during World War I and the interwar years, World War II saw both the Allies and Axis countries converting explosive-laden manned aircraft into RPAs (e.g., PB4Y-1, BQ-7) to be flown into enemy targets as guided cruise missiles or bombs.<sup>3</sup> In the 1970s the Air Force's BGM-34F fighter RPA and the highly maneuverable aircraft technology projects demonstrated how RPAs could outperform manned fighter aircraft.<sup>4</sup>

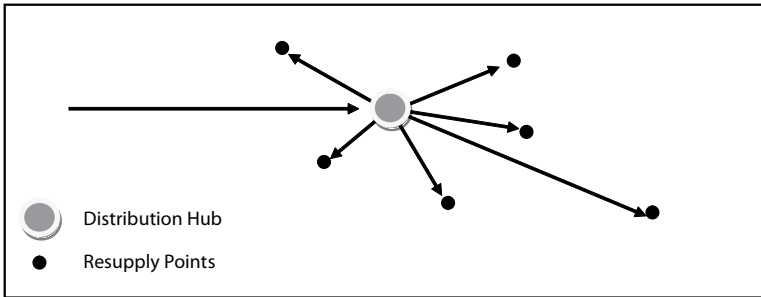
The current use of such RPAs as the Predator, Reaper, Warrior, and Global Hawk for armed and unarmed intelligence, surveillance, and reconnaissance (ISR) missions only scratches the surface with respect to medium and large remotely piloted platforms. While the use of persistent armed and unarmed ISR platforms in military operations has proven invaluable and ultimately essential to success on the battlefield, advancements in technology, increased needs, and shrinking budgets present the Department of Defense (DOD) with both challenges and opportunities. Op-

erational and budgetary limitations coupled with tooth-to-tail ratio, shrinking force size, increasing logistical requirements, and deployment footprint concerns dictate that we find solutions rapidly. We simply need to look at problems through a wider lens, consider all the tools available, and develop a solution, even if it means a significant paradigm or doctrinal shift. One area that deserves extra attention is the current and emerging capability gap with respect to tactical airlift and the role RPAs can play in addressing these limitations. An RPA designed to fulfill the joint tactical airlift requirements can offer an inexpensive, safe, flexible, and responsive option that can increase tactical airlift capabilities and save lives, even in conditions considered too hazardous for manned aircraft.

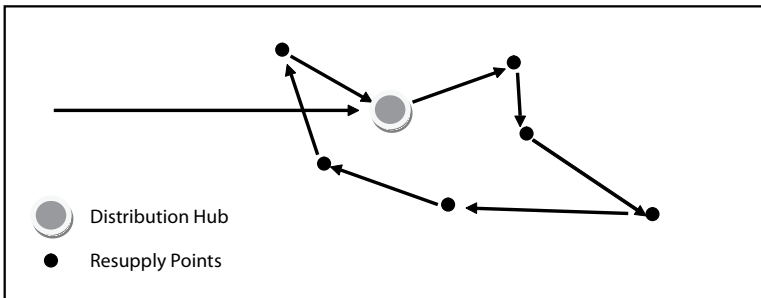
## **The Current Logistical System**

Under the current US Transportation Command system, cargo is moved from factory to foxhole via a spoke-and-hub system (similar to that used by commercial carriers). While the ideal system to the customer would be a movement of the personnel and equipment directly from the factory or home base to their final destination, this is far from efficient and certainly not realistic. Instead, strategic lift assets (i.e., ships and aircraft) move the cargo and passengers from their points of origin to the theater of operations through a series of major hubs. Once in theater, the personnel and equipment are typically moved to a distribution hub via a tactical lift asset where they await transport to their final destination via either a direct route (fig. 1) or a ring route/distribution circuit (fig. 2).

While the strategic lift portion of the factory-to-customer chain is well established and relatively efficient for routine shipments, the last tactical mile segment is less than ideal. The process of moving cargo, especially mission-critical (MC) and time-sensitive (TS) shipments, into places where a channel has not been established is considerably more complicated and time intensive.<sup>5</sup> Depending upon a combination of fixed-wing (e.g., C-17, C-130, etc.), rotor-wing (e.g., CH-53, UH/HH-60, CH-47, V-22, etc.), ground-transport (e.g., trucks, rail), host-nation, and contract transport using an assortment of fixed wing, rotor wing, and ground lift,



**Figure 1. Factory to distribution hub with spoke distribution.** (Created by the author.)



**Figure 2. Factory to distribution hub with ring route/distribution circuit.** (Created by the author.)

the last tactical mile segment of the cargo movement process is inefficient, typically service oriented, and in some cases extremely dangerous.

## Delays

Since World War II airlift has become an ever-increasing necessity to fielded forces for not only resupply but also transport to and from the fight. To be effective, fielded forces require sufficient supplies where and when required. Again, the answer has pointed to airlift. Improved responsiveness from the US logistical system has ultimately resulted in greater expectations for immediate results. Unfortunately, these expectations for short request to delivery times can have significant results when not met. Logistical limita-



tions, however, can and often do result in significant expected and unexpected delays for the personnel and equipment being transported.

These delays, which will ultimately affect the effectiveness of the fielded forces, can emanate from an assortment of reasons. For example, cargo and/or personnel may remain at a distribution point while they await transportation. Other delays may result from maintenance, crew availability (e.g., qualifications, crew rest), the lift asset making additional stops en route to the cargo's final destination, or even enemy action at the point of departure, en route, or at the final destination. Weather considerations, especially for helicopter operations, can also lead to delayed or even missed deliveries due to weather-avoidance considerations (primarily from obscured visibility conditions).

Two other significant causes of delay are terrain and aircraft availability. For example, in 2008 Marine Corps Combat Logistics Battalion 3 (CLB-3) was charged with moving supplies to forward locations 60–90 kilometers (km) away (straight-line distance) over unprepared and unsecured routes in Afghanistan. A 60-km (37.3 miles) route could take anywhere from 16 to 54 hours depending upon the extent of enemy action and mechanical problems. According to the unit's commanding officer (CO), the average 60-km patrol took approximately 20 hours to complete.<sup>6</sup> This equates to a straight-line speed of approximately 1.87 miles per hour. Despite an interest to move as much cargo via airlift as possible, the unit's access to only four CH-53s significantly hampered this goal.<sup>7</sup> In fact, due to airlift limitations the CLB-3 was able to airlift only 650,000 lb. (approximately 5.5 percent of the supplies) using CH-53s. The remaining 11.2 million lb. of supplies were transported via ground convoy.<sup>8</sup> Even along routes with established roads, force-protection considerations typically result in low-movement rates, particularly in areas at high risk of an improvised explosive device (IED) or enemy force contact.

Regardless of the reason for the delayed delivery, the bottom line is the same: the passengers and equipment are delayed arriving at their final destination. These delays can have a direct impact upon the safety and effectiveness of fielded forces and convoy personnel.

## **Airlift**

The movement of supplies and personnel in the last tactical mile from supply hub to point of need presents a series of significant challenges to the war fighter ranging from security of the logistical lines of communication to simple environmental concerns. In Operations Enduring Freedom (OEF) and Iraqi Freedom (OIF), insurgent and enemy force tactics coupled with limited infrastructures have made the transport of supplies via ground both deadly and slow. These challenges have led to an increased reliance upon a combination of airdrop and airland flights using fixed- and rotor-wing assets to move supplies and personnel from major hubs directly to their points of need when required using the most expeditious and advantageous means available. Weather and terrain, however, have resulted in delayed movement or a requirement to move the supplies by alternate means.

In Afghanistan the general lack of passable roads to remote villages, forward operating bases (FOB), and deployed troops makes airlift the only viable option for resupply for many locations. In fact, while FOBs have taken advantage of the limited number of runways, only about 24 percent of FOBs can be serviced by C-130 or larger aircraft.<sup>9</sup> This lack of essential airland infrastructure has made vertical takeoff and landing (VTOL) airlift, ground convoy, and airdrop essential pieces of the logistics system in Afghanistan.<sup>10</sup>

To address these needs and limitations, the Army and Marines rely heavily upon formations of rotor-wing and tilt-rotor airlift assets (primarily by flights of CH-47s, UH/HH-60s, CH-53s, and V-22s) to transport much-needed supplies and personnel.<sup>11</sup> As most resupply is routine and predictable (with locations changing as forces move within the area of operations [AO]), regularly scheduled supply routes can be and typically are established. For example, to service established operating locations, the Army flies helicopters on regularly scheduled ring routes to multiple locations regardless of the amount or nature of the cargo being moved (fig. 2). This system, like a city bus route, allows cargo or personnel to get on the aircraft at any point along the circuit for transportation to another location along the route.

A significant problem with this system is that aircraft may fly with underutilized cargo space and/or passenger seats to locations that don't have inbound or outbound cargo or passengers. This process wastes fuel and time while exposing the flight crew and passengers to unnecessary risks. Cargo and/or passengers may also have to transit multiple locations before they arrive at their intended destination, resulting in unnecessary delays. While this system is far from efficient, it is predictable, convenient, and easy to schedule.

Fulfilling the short-notice, small load, and passenger lift requirements is a combination of standby rotor-wing assets and an assortment of private and commercial fixed and rotor-wing carrier contracts (appendix 1 has additional contract asset information). While the total amounts moved by these carriers pale in comparison to those lifted by military assets, these companies have provided a significant number of VTOL and short takeoff and landing (STOL) flights with loads ranging from a few hundred pounds to over 35,000 lb. In Afghanistan alone from January to June 2009, civilian rotor-wing aircraft averaged 3,357 lb. of cargo and 40 passengers per mission, and civilian fixed-wing aircraft averaged 1,166 lb. and six passengers per flight. These routine flights free up critical airlift assets for other missions and reduce aircraft utilization.<sup>12</sup> While providing a crucial lift capability, the nature of this service imposes restrictions on the types and quantities of cargo that can be lifted by these assets, particularly about destinations and sensitive cargo, passengers, and missions.<sup>13</sup>

Augmenting the airland capabilities is a steadily increasing airdrop capability, capacity, and utilization, a trend that will probably continue in current and future conflicts. However, with limited access to large, secure drop zones, conventional airdrop has proven insufficient to keep fielded forces in rugged terrain supplied. To address this challenge, the Army has turned to the \$100 low-cost, low-altitude (LCLA) airdrop system. Capable of landing within 50 meters of the intended target, this system helps to ensure the needed supplies (typically dropped in 250–560 lb. bundles) remain within the immediate area of the troops. Another advantage of this system is that it does not require drop-

zone (DZ) surveys before delivery, thereby enhancing delivery responsiveness.<sup>14</sup>

LCLA is a critical mode of distribution to platoon and platoon-sized locations. The accuracy of the LCLA method of airdrop prevents units from having to go outside of the wire to receive supplies because bundles of CL I, III, and V can be dropped inside of a very small window. This is critical because many of these locations do not have enough Soldiers on hand to provide force protection and secure a DZ and recover airdrop bundles simultaneously. In addition, the LCLA platform can be used to resupply Soldiers on patrols or in Ops [Operations]. The materials used to build the bundles are expendable, allowing patrols to receive the supplies and leave behind the packing material with no retrograde requirements.<sup>15</sup>

A significant drawback of the LCLA system, however, is the delivery method. System limitations require the drop to be made in good weather from a low altitude during daylight.<sup>16</sup> This requirement makes the delivery aircraft a vulnerable target and highlights the position of friendly forces. In situations where an LCLA airdrop isn't feasible, the required supplies can be dropped from an altitude of over 25,000 feet using the joint precision airdrop system (JPADS) and the improved container delivery system with the same level of accuracy.<sup>17</sup> These systems have not only increased aircrew safety but they have also allowed for standoff airdrop at night, which can help mask the location of friendly forces on the ground.

The combination of additional need and greater accuracy has led to an exponential increase in aerially delivered supplies.<sup>18</sup> Two serious drawbacks of JPADS, however, are that it is far more expensive than the LCLA, and it requires some equipment to be extracted following delivery (effectively increasing combat load and/or helicopter support requirements). Unfortunately, however, for locations such as along ridgelines and where troops are engaged in proximity to the enemy, 50-meter accuracy is still insufficient. In these cases, supplies that miss the small target area may ultimately be lost or even recovered by enemy forces. Yet the supplies must still be delivered by ground transport or VTOL assets. Another noteworthy drawback of the airdrop option is that it takes an average of 72 hours for a forward location's request for supplies to be answered if the requested supplies are already in theater and several more days if the supplies need to be lifted in.<sup>19</sup> While this may be acceptable for such routine supplies as

food and water, which can be routinely scheduled and stock-piled, this turnaround time is too long for troops engaged with the enemy. The TS mission needs have led to a high reliance upon the limited rotor-wing TS/MC lift assets. The limited available airlift capacity has also left ground convoys as the primary means of cargo movement.

Regardless of the benefits, the heavy reliance upon and utilization of VTOL assets has not come without a cost. Harsh environments and constant use have strained and prematurely aged the limited fixed- and rotor-wing assets that the United States has become dependent upon.<sup>20</sup> For example, the CH-47 is currently performing the majority of the Army's MC/TS and personnel movement in the OEF/OIF theaters because it is the best Army-owned asset available. Unfortunately, however, this added mission role has negatively impacted the CH-47 fleet's ability to perform its primary mission functions in support of the ground combat units. More to the point, by diverting these crucial assets from the ground combat units, the fielded forces are granted reduced access to a highly flexible and capable transportation asset. The persistent use of formations and the extended operational requirements (including flight frequency and ranges)—coupled with harsh desert environments—have also “generated a significant increase in the maintenance require[ments] for these aircraft.”<sup>21</sup>

Despite the current airlift limitations and costs, the extensive OEF and OIF air bridges have saved countless lives and supplies. Air Mobility Command's (AMC) addition of the C-17 to the overtaken C-130 tactical intratheater airlift fleet, coupled with the Army's and Marine Corps's shift in the utilization of VTOL assets to support more cargo movement needs, has significantly increased airdrop and airland service, “decreas[ed] the need for hazardous ground convoys . . . and saved lives.”<sup>22</sup> The increased airlift has also increased the responsiveness and speed of TS/MC supply delivery. Despite these accomplishments, approximately 80 percent of supplies are still transported by ground convoy.<sup>23</sup>

## **Safety**

All resupply flights, especially in combat situations, can and often do expose crews and aircraft to a wide assortment

of safety hazards, long duty days, enemy fire (in combat zones), and environmental hazards (e.g., brownout, whiteout, icing, rain, and instrument meteorological conditions). For example, between 11 September 2001 and 14 December 2009, spatial disorientation, brownout, and whiteout conditions directly contributed to 10 Air Force and 55 Army rotor-wing mishaps in the Iraq and Afghanistan area of responsibility (AOR). Between 11 September 2001 and 18 August 2008, the Navy experienced five Class A mishaps in the CH-46, HH-60, and UH-1 aircraft. Together these mishaps resulted in zero Air Force, 49 Army, and 15 Navy/Marine Corps fatalities.<sup>24</sup> Such human factors as “get-home-itis,” “mission-itis,” fatigue, overconfidence, and deviations from standards can also significantly increase the chances of a crew being involved in a mishap. Crew duty-day limitations coupled with crew rest-location limitations and mission expectations may place additional pressure, stress, and ultimately risk upon a crew.

While the danger to flight crews is notable, the current danger to ground personnel is far more significant. While ground convoys can carry significantly more cargo than tactical airlift assets, the slow speeds of ground convoys result in the convoy personnel being exposed to threats for extended periods. In high-threat environments, extended threat exposure times have direct safety implications upon the personnel involved in the convoys (typically from two to three personnel per vehicle). In fact, from 19 March 2003 to 30 September 2007, 1,503 US service members died from IEDs in Iraq alone. An additional 133 died of car bombings. While not all of these fatalities occurred during resupply ground convoys, they do illustrate the significance of the problem. In fact, car bombs and IEDs were the leading causes of death in Iraq (43 percent), followed by hostile fire (31 percent).<sup>25</sup> Likewise, in Afghanistan, from 2003 through 8 December 2009, 309 US fatalities occurred due to IEDs. This equates to 47.8 percent of all US fatalities due to hostile action in Afghanistan during this period (35.4 percent of all US fatalities during this period).<sup>26</sup> Since 2001 these constant threats have also resulted in the loss of critical supplies and vehicles while simultaneously having a direct impact upon public perception (both US and foreign) and costs.

## **Overview**

As several other studies have already been conducted on the feasibility of unmanned strategic airlift, this study assesses the use of RPA for the last tactical mile or unmanned intratheater airlift. More specifically, this study addresses these questions: (1) What operational requirements exist that would justify the employment of an RPA platform in the tactical environment? (2) Will current and forecast RPA technologies fulfill these requirements? and (3) How might these assets be employed?<sup>27</sup>

The next chapters build upon the background information presented in chapter 1. Chapter 2 discusses the operational requirements of fielded forces, and chapter 3 investigates existing and future RPA technologies that may be used to fulfill the identified requirements. Chapter 4 offers suggestions for a tactical airlift RPA (hereafter referred to as MQ-A), with chapter 5 offering a concept of employment for that platform.

## **Assumptions**

Recognizing that a move to a remotely piloted intra-theater airlifter may be a significant paradigm shift, this study assumes that the MQ-A will be used for transporting supplies and equipment until the safety of an RPA is demonstrated and people are willing to be transported by an aircraft without a pilot on board. Furthermore, the author assumes that RPAs will augment existing lift capabilities either through semiautonomous or autonomous operations.

Additionally, while the Air Force gained the responsibility of providing the Army's strategic and tactical airlift according to the Key West Agreement of 1948, this study does not presume which service(s) will operate the MQ-A once it is acquired.<sup>28</sup> In the past, strategic lift was provided by US Transportation Command and is thus inherently joint in nature. The strategic lift segment, however, simply moves the personnel and equipment from the point of origin to a supply hub within the AOR. Once there, each service has typically been left to arrange its own lift (either internally or with a sister service) to the forces in the field. This practice

has led to a close logistical relationship between the Army and the Air Force, but it has also resulted in the acquisition of service-specific lift assets.

While this has traditionally offered each service the flexibility to employ its resources when and how desired (to include single-service operations when so tasked) to control its own supply chain, this method can lead to unnecessary redundancy and/or inefficiencies in a joint environment. Acquiring a common, multirole platform, however, would improve the acquisition of aircraft components and modules, servicing, and maintenance, and general familiarization and use in a joint environment. With this being said, the study makes no assumptions regarding who will or should operate the MQ-A, suggesting only that its acquisition and employment be focused on the joint requirements. Ultimately, the joint commands and the services will need to decide whether US Transportation Command, US Joint Forces Command, a single service, or a combination of services will be responsible for the last tactical mile of the factory-to-foxhole logistics chain.

## **Summary**

In both Afghanistan and Iraq, US forces proliferate over large geographic areas. While not significant in itself, that only a small fraction of these locations are collocated with an airfield and a majority of them are connected by insecure lines of communication mean the task of resupply is both arduous and hazardous. Ground convoys, the primary source of resupply to forward locations, are significantly impacted by existing road systems and frequent attacks, factors that have driven a demand for more airlift.

The current tactical airlift system, although effective, lacks sufficient numbers and the responsiveness and flexibility required by the fielded forces. The fixed-wing airlift system is dependent upon limited runway availability and the accuracy of imprecise airdrop systems servicing challenging troop positions. Meanwhile, range, environmental considerations, speed, and payload limitations significantly affect the limited number of lift helicopters. Enemy activity/threats, weather, crew availability, and aircraft availability further affect all airlift assets. Making matters worse, an



insufficient number of tactical lift assets is available to fulfill the lift needs.<sup>29</sup>

While the current logistical system has served the United States well, current and emerging threats and resource availability have made the continuation of existing practices extremely costly. What is needed is a system that is more responsive and capable of meeting the war fighter's needs with minimal risk to aircrew and expensive aircraft. The answer to this dilemma will most likely require a logistical paradigm shift.

### Notes

1. In accordance with HQ AF Flight Standards Agency Message A3A-10-01-Unmanned Aircraft System (UAS) Terminology Clarification, 14 January 2010, "Unmanned aerial vehicles" (UAV) will now be referred to as "remotely piloted aircraft" (RPA). When referencing the entire system (i.e., RPA and GCS), the system will be referred to as an unmanned aircraft system (UAS). The terms *unmanned* and *unmanned aerial vehicles* (UAV) will be used throughout this paper when the term is part of a formal title, a program description, is used in a direct quote of another source, or references its use in another document. RPA will be used in all other cases.

2. Taylor, *Jane's Book of Remotely Piloted Vehicles*.

3. NOVA, "Time Line of UAVs."

4. McDaid and Oliver, *Smart Weapons*, 131; and Deets and Purifoy, *Operational Concepts for Uninhabited Tactical Aircraft*, 12-3.

5. Demetrius Glass (Logistics Management Specialist, Army Logistics Innovation Agency, Army G4), interview by the author, 14 January 2010. Glass was previously assigned to the Mobility Airlift Command, Air Staff, Joint Staff (J-4), and US Transportation Command.

6. Jernigan, to the author, e-mail, 10 December 2009. The e-mail contained information on typical combat logistics patrols for 1st Marine Logistics Group (Iraq 2006-2007) and 3d Marine Logistics Group (Afghanistan 2008-2009). The e-mail attachment, "Typical Afghanistan CLP Breakdown," included firsthand information on his units' performance during these periods.

7. Jernigan, "Typical Afghanistan CLP Breakdown."

8. Ibid.

9. According to the Central Intelligence Agency, Afghanistan had 16 paved and 35 unpaved runways (less than half the number of runways as can be found in Iraq). See Anderson, *OEF, COPs, and Bases.xlsx*.

10. VTOL airlift refers to all fixed-wing, rotor-wing, tilt-rotor, and any other platforms capable of conducting a vertical take-off and landing.

11. Current doctrine calls for rotary-wing assets to fly always in formations of two or more aircraft regardless of the load being transported. This includes flights to move a small number of passengers or small cargo item(s) even if one or more of the aircraft will be empty. While this practice

enhances force protection, it is expensive, inefficient, and increases maintenance requirements.

12. In Afghanistan from January to June 2009, civilian fixed-wing carriers flew 4,700 sorties (4,686 of which were STOL flights) as compared to just over 1,600 US military fixed-wing flights (i.e., C-5, C-17, and C-130) with average cargo loads of 1,166 lb. and 14,812 lb., respectively.

13. Donald Anderson, YD-03 (assistant director, analyses, assessments, and lessons learned, AMC/A9), interview by the author, 19 January 2010. Data is based upon US Transportation Command Flying Hour and Monthly Activity Log spreadsheets provided by Anderson.

14. 101st Sustainment Brigade, "Lessons Learned," 1.

15. 801st Brigade Support Battalion, "Lessons Learned," 17.

16. 101st Sustainment Brigade, "Lessons Learned," 1.

17. Benney et al., "Joint Medical Distance Support and Evaluation," 3, 5-7; Kauchak, "New Joint and Service Solutions"; and Natick Soldier Research, Development and Engineering Center, *Precision Airdrop Technology Conference and Demonstration 2007*.

18. Buxbaum, "Technological Advances."

19. Anderson, interview. In Afghanistan alone, airdrop increased from approximately "2 million pounds in 2005 to 16.6 million pounds in 2008."

20. Manske, *Unmanned Airlift*, 8.

21. Vice chief of staff Army/vice chief of staff Air Force, *USAF Direct Support*, 7.

22. Lichte, "Commander's Intent," 2.

23. Maj Robert Hilliard, US Transportation Command/J3, to the author, e-mail, 16 February 2010. Actual quantities of supplies and personnel transported via rotor wing and ground transportation were unavailable due to limitations in the current logistical tracking systems. While US Transportation Command and Air Military Command track cargo airlifted via Air Force lift assets (to include airdrop), once the cargo is offloaded and transferred to the Army and Marine Corps at a forward supply location (e.g., Kandahar, Bagram, Baghdad, etc.), the cargo is considered "delivered to destination." The "last tactical mile" movement of the supplies by rotor wing and ground transportation from this supply depot to other FOBs is tracked and kept by the individual units performing the supply movement (i.e., each combat air brigade maintains its own records). The lack of a central unifying database has made it virtually impossible to obtain reliable theaterwide intratheater cargo movement data. Without this data, an accurate comparison among quantities moved by airdrop, rotor wing, tilt rotor, and ground transport could not be made.

24. Information obtained from the Air Force Safety Automated System (AFSAS), Navy Safety Center, and the Army Combat Readiness/Safety Center show that 36 of the 55 Army mishaps (resulting in 47 fatalities) involved cargo and troop-carrying aircraft. The remaining mishaps involved OH-58s and AH-64s. The overall spatial disorientation and visual obstruction mishaps for the Air Force, Army, and Navy/Marine Corps equaled 70 mishaps and 64 fatalities.

25. O'Hanlon and Campbell, *Iraq Index: Tracking Variables*, 18.

26. iCasualties.org., "Operation Enduring Freedom."

27. Mission-specific cargo load information, to include airlift, airdrop, convoy data, and supplied locations, is classified. However, although some of the resources reviewed in preparation for this paper are classified, the material presented in this paper is unclassified to ensure widest dissemination. Specific classified load data is maintained by US Transportation Command and by each service's logistical agencies.

28. Under the Key West Agreement of 1948, which defined the functions of each service, the Army retained responsibility for ground operations, and the Air Force was given responsibility of air operations. Particularly, the Army retained responsibility for ground operations to include ground-based air defense, but it relinquished the role of close air support, strategic airlift, and tactical airlift to the Air Force and sealift to the Navy. The Air Force gained the responsibility for strategic airlift, tactical airlift, close air support, strategic aerial warfare, and defense of the United States against aerial attack. The Navy was allowed to retain the Marine Corps (along with its aviation arm) and its own aircraft for air transportation. In the time since the Key West Agreement, the Air Force has, for the most part, moved from the tactical airlift role (outside the support provided by the C-130 and C-17) while the Army has filled this niche with its rotor-wing fleet. See Maj David D. Dyche, Air Force, *Military Reorganization*.

29. Hayes, "MAF/SOF/Helo Assignments." In addition to there being insufficient assets in theater as of the end of 2009, the Air Force has a rated-officer deficit of 1,520 and will have an expected deficit of 1,836 in 2014.

## Chapter 2

### **Operational Requirements**

*[The] DOD appears to have addressed its strategic airlift gap, but there is a potential future tactical airlift gap.*

—US Government Accountability Office 10-67  
“Defense Acquisitions”  
November 2009

*Time sensitive/mission critical mission requirements create demand for delivery of equipment, supplies, and personnel that are generally non-routine in nature and must be delivered to the point of need/point of effect in an accelerated time. These demands require the lift capacity to be supremely responsive to the supported commander’s immediate operational or tactical priorities. TS/MC demands cannot routinely be accommodated via the planned resupply and movement processes where efficiency is the primary consideration.*

—Department of Defense (DOD)  
*Quadrennial Roles and  
Missions Review Report*  
January 2009

By request of the DOD, the Government Accountability Office (GAO) conducted a study to “(1) identify the status of the DOD’s modernization and acquisition efforts and (2) determine how well the DOD is addressing any capability gaps and redundancies.”<sup>1</sup> While conducting the study, the GAO determined that the DOD had addressed identified strategic airlift gaps but had failed to adequately address a potential tactical airlift gap. The report, released 12 November 2009, states that although the DOD currently fulfills the medium tactical-airlift requirements with the C-17 and the C-130, considering access limitations, this is an insufficient long-term solution.<sup>2</sup> The current plan is to replace the C-17 with the C-27J in this role, but the C-27J is not expected to be operational for at least another 15 years. Furthermore,

questions remain regarding whether the C-27J will fulfill the DOD's medium-lift needs, especially with a reduction in aircraft from 78 to 38 and its inability to perform VTOL.<sup>3</sup> Unfortunately, these options fail to address the fact that approximately only 19 percent of supplied locations in Iraq and Afghanistan are accessible by fixed-wing aircraft (except by airdrop) and even fewer by C-130 or larger aircraft.<sup>4</sup> Granted this statistic is only for current operations in Iraq and Afghanistan, but planning for tomorrow's fight cannot ignore the fact that the United States has a long history of having troops operating in relatively inaccessible locations with poor logistical infrastructures (e.g., Korea, Vietnam, Africa, Afghanistan, Pacific Islands, and South and Central America).

Furthermore, while the study addresses the movement of such large equipment as the Stryker and future medium-weight armored vehicles in theater, it does not address the need nor the methods used to supply troops who are geographically separated from runways. Additionally, it does not address the significant number of resupply flights to forward operating locations carrying relatively light loads (less than 3,000 lb.). This predictable and routine requirement is currently being fulfilled by ground vehicles and a limited number of VTOL aircraft, assets that could be used for larger loads, troop transport, and more complicated missions.

In addition, considering the relative successes terrorists and insurgents have had with IEDs in Iraq and Afghanistan regarding attrition of forces and influencing public opinion, it is reasonable to expect that these tactics will continue in future conflicts. It is also reasonable to expect a persistent requirement to secure our lines of communication and to reduce the risk to US and allied service members via tactical airlift of personnel and equipment. Unfortunately, current supply movement requirements exceed airlift capabilities as evidenced by the United States' near-maximum use of available airlift assets and its continued dependence upon ground and contract transport for a majority of its supply needs. These requirements for increased tactical airlift will require a shift in current tactical airlift doctrine and inventory.

## **The Search for an RPA Solution**

In May 2005 the Senate Armed Services Committee Report 109-69, *National Defense Authorization Act for Fiscal Year 2006*, stated that “the committee notes that dedicated unmanned aerial vehicles for movement of equipment and supplies could support Army expeditionary forces while reducing logistics, procurement, and operational costs.”<sup>5</sup> It went on to direct the secretary of the Army to investigate and report findings regarding requirements, technical feasibility, and the cost of integrating remotely piloted aircraft systems for resupply into the future force unmanned aviation concepts of aerial vehicles.<sup>6</sup>

In October 2007 the John Warner National Defense Authorization Act for Fiscal Year 2007 highlighted the congressional preference for unmanned systems on the battlefield. It also required certification that an unmanned system is incapable of meeting the needs of the Department of Defense for acquisition of a manned system to proceed. The secretary of defense was also required to identify “missions and mission requirements, including mission requirements for the military departments and joint mission requirements, for which unmanned systems may replace manned systems” and to identify “a strategy and schedules for the replacement of manned systems with unmanned systems in the performance of the [identified] missions” (appendix 2, section 941, addresses the DOD policy on unmanned systems).<sup>7</sup>

In January 2008 Army Combined Arms Support Command (CASCOM) received a tasking from the Army Training and Doctrine Command to support the Army’s obligation to respond to the 2005 congressional tasking (109-69). Less than two months later, CASCOM produced a short paper, *Logistics Re-supply Role of Unmanned Aircraft Systems (UAS) Concept of Employment/ DOTMLPF Analysis*, describing logistics roles for UASs. This document also included an initial concept of employment and a doctrine, organization, training, materiel, leader development and education, personnel, and facilities (DOTMLPF) analysis. The paper established a foundation for a more extensive analysis of logistics missions for UASs and their integration into the Army’s future modular force. In August 2008 CASCOM obtained

funding from the Department of the Army (DA) G-4 to support the Army Regulation 5-5 study focusing on a UAS resupply role. At the same time, DA G-4 also funded a concurrent RAND study that concentrated on other logistics applications for UASs.<sup>8</sup>

The Marine Corps followed suit shortly thereafter followed by the Air Force. The 18 May 2009 *United States Air Force Unmanned Aircraft Systems Flight Plan 2009-2047*, signed by the secretary of the Air Force, Michael B. Donley, and the Air Force chief of staff, Gen Norton A. Schwartz, proposes UASs as a means to “increase the percentage of assets available for operations due to the distributive nature.” In addition to highlighting several desired attributes, it forecasts the acquisition of an MQ-L, a large RPA capable of “ISR, EW communications gateway and air mobility operations” by 2020.<sup>9</sup> Subsequent discussions, however, suggest that an actual employment date (for at least a tactical lift UAS) would occur far sooner. Then, on 25 September 2009 AMC/A7 and A8 released a request for information (RFI) for unmanned cargo aircraft to build a forum for discussion on the subject and as a means to assess current and emerging technologies. The ensuing unmanned intra-theater airlift conference not only reviewed existing technologies and concepts but also helped to set the groundwork for establishing potential joint requirements.<sup>10</sup>

## **The Requirements**

It is worth noting that to date, no formal list of tactical airlift capability gaps, or “needs,” has been officially released by the Air Force or the Army. The Marine Corps has, however, released the *Universal Needs Statement (UNS) for the Cargo Unmanned Aircraft System (Cargo UAS)*, dated 27 August 2008. Considering this document and the arguments made through various mediums, including the AMC Unmanned Intra-Theater Airlift Conference (17–18 November 2009), the author proposes the following “needs” for consideration:

1. Increase responsiveness through on-demand airlift for small loads (less than 3,000 lb.)<sup>11</sup>

2. Remove, or at least reduce, the number of supply trucks on the road
3. Mitigate the impact of tactical airlift aircraft and aircrew shortages (without significantly increasing carbon footprint)
4. Increase airlift capacity, accuracy, and responsiveness of delivery (without significantly increasing manpower)<sup>12</sup>

The bottom line is that the fielded force needs more, or at least an improved, tactical airlift. With the exception of predictable resupply needs (e.g., food, water, and toiletries), many MC and TS needs arise that require timely fulfillment. Unfortunately, regularly scheduled resupply routes may prove too inflexible, and airdrop frequently takes too long from request for delivery. Regarding airdrop, several locations (e.g., ridgelines, mountainsides, along bodies of water, populated areas, and inside a besieged compound), including forces engaged in close contact with the enemy, cause airdrop to be too imprecise and too dangerous. In these cases, accuracy of a few meters on a pallet containing essential supplies could mean the difference between success or failure or survival. What is needed is an accurate, flexible, and timely delivery system.

While the logistical system currently in use by the DOD is robust and capable for a Cold War conflict, it presently struggles to meet the demands of irregular warfare as being prosecuted today, especially for the last tactical mile. Not surprisingly, the locations and types of operations conducted by each service have led to a diverse set of tactical airlift requirements. In fact, each service has established its own set of requirements (appendix 3) for an MQ-A tailored for their specific needs.

Considering the DOD's ever-increasing joint focus and its limited budget, it is highly likely and arguably preferable that a single multifunctional platform be acquired that fulfills all the needs of each service. With this in mind, table 1 summarizes the most stringent service requirements that must be achieved if all identified service needs are to be met. This is not to say that these are the only requirements



**Table 1. Joint RPA Requirements**

	<b>Joint Requirement</b>
<b>Transport &amp; Storage</b>	Can fit inside 20 feet TEU ISO Containers and a C-17 with minimal disassembly
<b>Ship Operations</b>	Amphibious with small footprint
<b>Assembly &amp; Operation</b>	Quick assembly
<b>Radius @ 1600-lb. payload</b>	500 nautical miles (nm) with 0.5 hours on station with cargo and a 2-hour intelligence, surveillance, and reconnaissance (ISR) loiter time
<b>Cargo Carriage</b>	Internal and external carrying capability with no external loading equipment required
<b>Speed</b>	> 250 knots
<b>Payload</b>	Up to 3,000 pounds
<b>Operations</b>	Autonomous, semiautonomous, land via soldier signal, beacon or at preset LZ, reusable, autonomous collision avoidance, contingency management
<b>VTOL Landing footprint</b>	Small, small for ships, urban ops, roads, FARPS & FOBs, unprepared surfaces
<b>VTOL Ops Altitudes</b>	12K Density (750 pounds, 75 nm radius RFP)
<b>En-route Ops Altitudes</b>	Cruise at altitudes outside range of most ground threats (antiaircraft artillery [AAA], surface-to-air missile, small arms), able to avoid highly congested altitudes
<b>Protection</b>	Small arms, large-caliber AAA, CBRN
<b>Operation &amp; Maintenance</b>	Rugged, reliable & low-maintenance hours/flight hour, "Flying Truck"
<b>Mission</b>	Multirole capable based upon attached module (airlift, ISR, electronic warfare [EW], close air support [CAS])
<b>Price</b>	Affordable, attrition acceptable (Air Mobility Command suggested \$10M)

**Source:** The individual service requirements can be found in appendix 3, Service RPA Requirements.

but rather that they are tactical airlift RPA requirements previously identified by each service.

Future tactical airlift assets must consider potential needs and requirements, not simply the needs of a single service. This requires designing a platform to address the limitations outlined in chapter 1, the needs outlined in chapter 2, and the service-specific requirements summarized in table 1. Airlift assets must also consider the requirements outlined in the *United States Air Force Un-*

*manned Aircraft Systems Flight Plan 2009–2047*. Most notably, future RPAs must be “multi-mission, all weather, net-centric, modular, [with] open architecture,” capable of carrying standard loads, and potentially having an optionally manned capability.<sup>13</sup> Underlying all these attributes is a need to be responsive, flexible, safe, survivable, inexpensive, and reliable.

One of the advantages and shortcomings of manned aircraft is their ability to be responsive to rapidly changing requirements. Pilots are able to process a changing environment, assess changing requirements, determine the best course of action, and execute the adjusted plan. Another important aspect of responsiveness is the ability to have assets available to execute a mission when and where required. Unfortunately, however, environmental and enemy hazards coupled with crew rest requirements can result in manned aircraft not being available when required.

To ensure mission success, an MQ-A should be able to enhance the capabilities available through manned platforms. For example, a fleet of autonomous or semiautonomous RPAs would not be restricted by the aforementioned aircrew limitations or a chemical, biological, radiological, nuclear, and high-yield explosives (CBRNE) environment, thus making on-demand resupply a reality in diverse conditions. Having a semiautonomous RPA would also allow the aircraft to be retasked en route if required through the ground control station (GCS) or fielded forces via a portable uplink device (such as a personal digital assistant [PDA]). This MQ-A may be used to change a landing zone, put the aircraft in a holding pattern pending more favorable landing conditions, change missions (dependent upon on board modules), change routes, avoid obstacles/hazards, avoid ground threats, or return to base if the mission needs to be aborted. Given adequate sensors, an RPA can even achieve a sufficient amount of situational awareness to be fully autonomous in a rapidly changing environment, thereby further enhancing platform responsiveness and survivability while reducing manning requirements. A long-endurance time would further improve the aircraft’s operational flexibility, a key factor in future operations.

Mission flexibility is largely a product of having a modular-based design. Modularity, the ability of a system’s compo-

nents to be separated and recombined, allows a system to change missions based upon a selected payload. For example, attaching cargo pods to a given platform allows the RPA to be used for cargo transport while attaching ISR sensors, and weapons would allow the aircraft to be used in an armed reconnaissance role. Replacing the weapons with extra fuel tanks extends the persistence of the ISR platform over the selected target area. The potential also exists (given a large enough platform) to include or attach a cockpit and passenger module, thereby allowing the aircraft to transport passengers and operate in the existing international civil aviation organization (ICAO) national airspace systems (NAS) (including the United States). Effectively, aircraft capabilities and payloads can be tailored and scaled to meet specific mission requirements. However, to maximize the potential effects of a modular design, the system must also have an open architecture, thereby allowing components to be purchased from multiple suppliers/designers without proprietary concerns or expenses.

Critical to its ability to be customizable and flexible to mission needs is the aircraft's operations envelope. The most essential capability, considering the environments in which it will be operating and the limited accessibility of fielded forces, is VTOL. Another essential capability is an ability to operate at high speeds (resulting in shorter transit times and greater responsiveness), long ranges, and high altitudes (for threat avoidance, a more efficient transit, and mountain operations). To better meet Army and Marine Corps requirements, the aircraft should have the capability to carry a slung (oversized) load and must be able to load and unload its payload without the aid of external equipment. It must also be operable by both trained aircrew and the fielded forces that will be loading and/or unloading the airlifted cargo. Most importantly, it must be able to take off and land autonomously.

Another key aspect of any platform, manned or unmanned, is that it must be safe to operate. Regarding an RPA, the ground personnel who will launch, service, and recover the aircraft is of greater concern than is the flight crew. The aircraft's downwash must be conducted at velocities and temperatures suitable for humans to work in as must the engine noise levels. The aircraft must be able to

land at a designated location reliably with little risk to ground forces operating in the immediate vicinity.<sup>14</sup> Landing successfully will require it to have redundant systems, which will enable the aircraft to function and complete its mission in a hostile environment where satellite communication with the GCS is unavailable (lost link) and small arms fire may be encountered. This landing procedure must include the capability to operate in adverse weather conditions (to include brownout and whiteout conditions) and in conditions where visual, vestibular, or somatosensory hazards have traditionally resulted in large numbers of manned mishaps. It must also include all necessary sensors and autonomous maneuver capabilities to sense and avoid both airborne and ground hazards (including but not limited to aircraft, power lines, trees, buildings, and potentially even hostile fire). In other words, it must be survivable and reliable in all environments.

Regardless of an aircraft's capabilities, the less time an aircraft spends on the line, the less effective the system is. As such, an MQ-A must have a high reliability and utilization rate regardless of the operating environment. The avoidance of technologies or components that traditionally have high maintenance rates will help to increase reliability rates. Utilizing simple and proven systems and technologies will also help to reduce maintenance requirements and costs while increasing reliability and utilization rates. To ensure mission flexibility and responsiveness, the MQ-A must have a higher reliability rate than manned aircraft.

Despite how autonomous, survivable, and reliable the system may be, some aircraft ultimately will be lost. In effect, that is one of the advantages of utilizing an RPA instead of a manned aircraft: the ability to fly a mission in conditions that are considered unsuitable or too hazardous for manned aircraft to operate in hostile CBRNE, adverse weather, or outside a crew-rest window. As such, the cost of an MQ-A must be low enough that the fear of its loss is not sufficient to preclude using it in hostile (or even friendly) environments. In addition to the RPA itself being inexpensive, the entire system (including the GCS, support equipment, maintenance, and daily operating expenses) must also be low enough so as not to make the acquisition of the system cost prohibitive.

While *inexpensive* is a relative term requiring further quantification by the DOD, AMC has proposed \$10 million as a starting figure for the platform. This figure does not include specialized mission modules. To help keep the cost down and maintain a high reliability rate, an MQ-A must have a simple construction and a design that is both inexpensive to maintain and easy to repair. Reducing the system complexity, minimizing the number of moving parts, and using off-the-shelf or easily and inexpensively fabricated components are additional considerations.

To help keep replacement costs down and availability rates high, the RPA must be recoverable and reusable. Requiring supplied troops to carry the delivery vehicle with them degrades the performance of the fielded force. Likewise, requiring another manned flight to rendezvous with the fielded forces to extract the vehicle degrades overall mission effectiveness as it diverts that resource from another mission-essential task and slows down the operations tempo of the fielded forces. As neither option is acceptable, the RPA must be able to return to its main base of operations autonomously or semiautonomously with a short turnaround time.

## **Summary**

*The environment MAF forces will operate in and the threats they will face are rapidly changing. The expeditionary nature of our primary customers, the U.S. Army and Marine forces, and their increased numbers stress the importance of MAF forces in meeting our national strategy. We find the majority of today's air operations in theater are MAF missions and we can anticipate the high operations tempo for MAF forces will continue for the near term.*

—Gen Arthur J. Lichte  
*Air Mobility Master Plan: 2010*

A key to success is having the right personnel and material at the right place at the right time. This requires an efficient use of mobility assets. Assets that are under- or inap-

appropriately utilized (i.e., carrying low-priority cargo rather than high-priority cargo or carrying cargo that is more appropriately transported through other means) can ultimately result in forces that are less effective or even ineffective.

Regardless of the method used to transport personnel and supplies to the customer, the supplies must arrive on time, where needed, and in sufficient quantity to meet the needs of the customer. Unfortunately, the current tactical lift segment of the distribution chain is insufficient to support the current demand. Resource availability/limitations and troop accessibility form a magnitude of problems for the delivery of required supplies and personnel. The call for increased airlift to improve timeliness of cargo delivery and to reduce the threat to ground personnel has also increased demands and risks upon aircrew. With that being said, aircrew and aircraft limitations coupled with a desire to expose fewer ground and flight personnel to risks make the addition of more manned aircraft to the theater an unviable option.

Budget constraints leading to fewer large, expensive aircraft being purchased and sustained will require a more efficient use of available resources in an environment requiring greater airlift. This will require a modification of how current assets are utilized and/or the acquisition of additional airlift assets. The only way to increase airlift capacity (with existing assets) without significantly increasing our carbon footprint in the AOR is to reallocate asset usage. For example, increasing the number of fixed-wing airdrops, increasing general airlift ops tempos, and maximizing the use of available cargo capacity will all contribute to greater airlift capacity and efficiency. However, this will increase demands upon aircrew and aircraft resulting in increased risk to personnel and expedited aging of utilized airlift assets. It may also have a negative impact upon the movement of small packages and passengers within the theater.

With this in mind and considering the aforementioned restraints and requirements, the study argues that the best option would be to augment the existing lift capabilities with an inexpensive, autonomous/semiautonomous remotely piloted tactical VTOL airlift platform capable of meeting the current and forecast lift needs of the DOD. This option would provide enhanced, responsive, flexible, safe, surviv-

able, and inexpensive airlift without significantly increasing manpower requirements.

### Notes

1. US GAO, *Defense Acquisitions*.
2. Ibid., 33–34.
3. Ibid., 10–11.
4. Anderson, *OEF, COPs, and Bases.xlsx*.
5. US Senate, *National Defense Authorization Act for Fiscal Year 2006*, 237.
6. Ibid.
7. US House, *John Warner National Defense Authorization Act for Fiscal Year 2007*, 282.
8. Demetrius Glass (logistics management specialist, US Army Logistics Innovation Agency, US Army G4), interview by the author, 14 January 2010; and US Army Combined Arms Support Command, *Logistics Re-supply Role of Unmanned Aircraft Systems*.
9. US Air Force, *Unmanned Aircraft Systems Flight Plan 2009–2047*, 40.
10. AMC, *Unmanned Intratheater Airlift Conference*, conducted at Scott AFB, IL, 17–18 November 2009. Conference attendees included representatives from US Transportation Command, US Joint Forces Command, Air Staff A2U and A5X, Air Mobility Command, AF Research Laboratory, AF Squadron Officer College, Aeronautical Systems Center, US Army Training and Doctrine Command, US Combined Arms Support Command, Army Medical, Army G4, Office of Naval Research, Naval Air Systems Command, US Marine Corps, National Aeronautics Space Administration (NASA), US Air Force Academy, Air Command and Staff College and 11 private RPA contractors. The purpose was to discuss potential requirements for an unmanned intratheater airlifter, to determine whether AMC should pursue an unmanned tactical airlifter, and to gain an appreciation for current and emerging UAS technologies. US Transportation Command's future deployment and distribution assessment group, the US Army's UAS Working Group, the Air Force's UAS Working Group, and the Marine Corps's UAS Requirements office are also investigating/considering using unmanned cargo platforms.
11. Requirements are based upon comments made by Army, Marine Corps, and Air Force personnel in attendance at the *Unmanned Intratheater Airlift Conference*, sponsored by the Air Mobility Command, and through e-mail and phone conversations after the conference. Conference attendees are listed in note 10.
12. In Afghanistan from January to June 2009, civilian VTOL aircraft transported an average of 3,357 lb. of cargo per mission. Military VTOL cargo lift statistics were unavailable.
13. US Air Force, *Unmanned Aircraft Systems Flight Plan 2009–2047*, 33.
14. Significant hazards that must be considered include, but are not limited to, rotor contact, exhaust burns, noise levels, aircraft movement, and loss of controlled flight during approaches and landings.

## Chapter 3

### **Technology Review/Proof of Concept**

*Unmanned aircraft systems (UAS) and the effects they provide have emerged as one of the most “in demand” capabilities the USAF provides the Joint Force. The attributes of persistence, endurance, efficiency, and connectivity are proven force multipliers across the spectrum of global Joint military operations.*

—Michael B. Donley  
Secretary of the Air Force

*There is no longer any question of the technical viability and operational utility of UAVs. . . . The Task Force feels it is time for the DOD and the Services to move forward and make UAVs and UCAVs [unmanned combat air vehicles] an integral part of the force structure.*

—Maj Gen Kenneth Israel  
USAF, Retired  
Cochair, Defense Science  
Board Task Force on UAVs  
and UCAVs

Modern ISR platforms (including but not limited to the US Air Force’s Predator, Reaper, Global Hawk, and Sentinel aircraft) have repeatedly demonstrated the utility, reliability, and survivability of remotely piloted platforms in both hostile and nonhostile environments. Recent use of armed Predators and Reapers has further demonstrated the advantages of having persistent, remotely piloted armed ISR platforms in combat and has effectively secured a place for RPAs in the modern and future battlefields.

### **System Requirements**

To realize a maximum benefit from a remotely piloted cargo platform, the MQ-A must be able to perform most, if not all, functions autonomously while maintaining the capability to retask or operate the vehicle remotely to effect



mission changes when and where required. The aircraft must be able to be loaded and unloaded safely by ground personnel in all types of environments with minimal training. It must be capable of performing autonomous VTOL to and from forward flight with the ability for fielded forces to adjust the landing zone based upon the changing environment. While traveling en route between the supply location and the fielded forces, it must be able to navigate accurately to its destination, at the same time avoiding known ground threats (including obstacles and enemy troop formations) and airborne threats (including other aircraft) while carrying a cargo load and traveling at speeds far in excess of ground movement. It must also be able to quickly change roles based upon preloaded modules (e.g., cargo, ISR package, weapons, fuel tanks, and manned cockpit), and it must be able to accomplish this feat safely with little to no threat to ground personnel.

As basic RPA functionality (to include autonomous, semi-autonomous, and remotely piloted operations) has already been demonstrated through an assortment of existing fielded systems, this study does not address the feasibility of these features. What remains, however, is whether the technology exists to make the leap from current ISR platforms to fully autonomous or semiautonomous remotely piloted airlift platforms a reality in the near future and if not, to determine what is required.

Based upon the aforementioned requirements, the primary technologies of concern involve (1) multifunctionality (e.g., armed/unarmed ISR, and cargo), (2) propulsion, (3) fielded force landing-zone (LZ) modification, (4) autonomous VTOL, (5) threat avoidance, (6) collision avoidance, (7) autonomous or semiautonomous route creation and modification, (8) automating manned aircraft, and (9) safety, although the latter is more of a factor of design than technology.

## **Multifunctional/Modular**

The functionality of any system is based upon the system's design and components. Just as current manned systems can be used for multiple roles (e.g., the B-52 is being used as an ISR and weapons delivery platform, C-130 for cargo/troop transport and ordnance delivery, particularly

the massive ordnance air blast [MOAB]), so can an RPA have multiple roles. The key is that the design of the system must include the ability to perform multiple roles. Take, for example, the MQ-1B, which fired its first Hellfire missile on 21 February 2001. The Hellfire was originally designed as an ISR platform, and the addition of hard points and fire capabilities converted its platform from a nonlethal observer to a potential tank killer. This mission role change, however, does not prevent the system from being used in an ISR role. In this case the aircraft can be launched with a full load of fuel, or it can trade a few hours of flight time for a few Hellfire missiles.<sup>1</sup>

In a similar fashion, a basic RPA can be constructed to meet the specified joint performance requirements, and later its mission can be dictated by the modules that are attached to it before departure. For example, cargo can be transported on one mission in an external cargo module, and then the cargo module can be exchanged with an ISR module for the next mission. The ISR module can also be augmented with additional fuel or ordnance. Another module option might include a communications package that would allow the platform to serve as a communications relay station. Given a sufficiently large RPA frame, a manned cockpit module can be added to allow it to fly freely in the NAS, carry passengers, or perform complicated missions. The key, of course, is a modularly designed platform.

## **Propulsion**

To be effective in all required operating environments, the MQ-A must be equipped with a propulsion system that is not only VTOL-capable but also able to operate at high altitudes (above most ground threats and in mountainous terrain) and speeds (> 250 knots). The four primary technologies that currently provide VTOL capability include (1) airships, (2) rotor wing, (3) tilt-rotor, and (4) ducted fan.<sup>2</sup> This paper does not discuss airships, since they currently are unable to attain the required forward velocities (and arguably the required maneuverability and lift).

Currently, most airlift-to-fixed-wing-inaccessible locations are serviced by rotor-wing aircraft. With respect to rotor-wing unmanned platforms, the MQ-18 (utilizing a

four-rotor-blade design) can fly for more than 18 hours unrefueled, hover at 20,000 feet, and carry up to 2,500 lb.<sup>3</sup> As this technology is proven (in both manned and unmanned platforms) and widely known, it does not warrant further discussion here with respect to proof of concept in this study. However, this technology does have limitations. Foremost is forward velocity. Aerodynamic limitations restrict rotor-wing aircraft to a forward velocity of approximately 250 knots.<sup>4</sup> This rotor-wing speed limitation, however, can be overcome with special high-speed blades or a stowed rotor design.

Stowed rotor aircraft use a rotor wing to function as a helicopter during takeoff and landing phases of flight and another propulsion system for forward flight (either jet or propeller). Upon reaching a safe altitude after takeoff, a stowed rotor aircraft transitions to its cruise propulsion system and “stows” the rotor blades for the en route segment of flight. Upon reaching its approach or descent point, the aircraft slows, deploys its rotor, transitions to the rotor wing for primary flight, and performs a vertical landing. Slowed rotor technologies provide a slight variation of this simply by disengaging the rotors from the transmission after transitioning to the forward propulsion system. This method allows the rotors to auto rotate and still provide some rotational lift to supplement the wings, but they no longer are the primary means of propulsion. The rotors are reengaged for landing when the aircraft slows to a safe operating range. In September 1998 Carter Aviation Technologies completed its first successful flight of a five-seat slowed-rotor compound aircraft and demonstrated several advantages over conventional helicopters.<sup>5</sup> The CarterCopter Technology Demonstrator has since achieved speeds in excess of 150 knots with future models expected to reach speeds up to 435 knots.<sup>6</sup>

Such tilt-rotor aircraft as Bell Boeing’s V-22 use two or more rotor-wing systems to take off vertically in the same manner as a helicopter but then rotate to a forward-flight configuration to effectively convert the aircraft from a helicopter into a traditional propeller aircraft. The rotors then rotate back to a vertical configuration for landing. The V-22 is able to lift up to 20,000 lb. of cargo internally or 15,000

lb. in a slung-load configuration and can fly at altitudes up to 25,000 feet (aircraft is unpressurized).<sup>7</sup>

Ducted- or lift-fan technologies, although less commonly known, have been in existence for almost as long as tilt-rotor aircraft. Ducted-fan aircraft use a standard forward-thrust turbojet or turbofan engine that provides forward thrust while in forward flight. However, when performing hover or VTOL, engine bleed or exhaust air (e.g., Northrop Grumman's XV-5A), or an auxiliary drive shaft (e.g., Lockheed Martin F-35) is used to power multiple internal ducted fans or blowers that produce vertical thrust. Another option is to simply redirect the thrust produced by the primary engine through internal ducting to outflow valves (e.g., Boeing/BAE AV-8B Harrier II). While in forward flight, the fans and valves are covered or put into an aerodynamic configuration, and the main engine provides forward thrust at speeds and altitudes equivalent to other jet aircraft.

In these aircraft, engine thrust dictates the amount of vertical lift and directional outflow valves, puffers, or louvers used to affect pitch, roll, and yaw. Ryan's XV-5A (flown during the 1960s), for example, used lift fans powered by engine bleed air to provide vertical lift in the same manner as a standard helicopter without any exposed blades. While stability problems plagued early ducted-fan aircraft, current technologies make this propulsion system stable and less complex than standard rotor-wing and tilt-rotor propulsion systems.

While all four propulsion systems are proven technologies and are able to provide VTOL capability, the aircraft requirements outlined in chapter 2 tend to favor some technologies over others. For example, stowed rotor aside, the standard rotor-wing and tilt-rotor aircraft tend to be limited in forward speed and altitude. They also have large ground footprints (due to blade length), which in turn limit potential landing zones. The exposed blades also present a safety hazard to ground personnel operating in the immediate vicinity of an idling aircraft (particularly in areas of uneven terrain). The exhaust of tilt-rotor engines also creates a significant safety hazard. While the engine is in the VTOL configuration, engine exhaust is ported to the ground at temperatures in excess of several hundred degrees Celsius.

Ducted- or lift-fan aircraft, on the other hand, have several advantages. Ducted-fan aircraft, like traditional rotor-wing aircraft, have low downwash temperatures.<sup>8</sup> Unlike rotor-wing aircraft, however, they have no exposed rotor blades, can quickly shut down or hide the lift fans by cutting off the exhaust air to the fans and/or by closing the access doors, thereby eliminating downwash while on the ground, and don't have complicated, heavy transmission systems like rotor and tilt-rotor aircraft (reducing weight, maintenance requirements, and cost). Because they do not employ long rotor blades, ducted- or lift-fan aircraft have smaller footprints that allow them to operate in and out of more confined spaces. Additionally, in-wing ducted-fan designs fly at altitudes and speeds equivalent to jet aircraft.

### **Fielded Force Landing-Zone Modification**

A distinct advantage of operating manned aircraft is the ability to adjust the mission execution when and where required. This includes the adjustment of a potential landing zone based upon the requirements of the dynamic environment. This need does not change when RPAs are introduced into this same environment. While pilots located in geographically separated GCS's can alter the course, communication requirements between the ground personnel, aircrew, and aircraft make this option challenging at best.

To address this issue, Northrop Grumman, during the Agile Lion demonstration in December 2005, displayed the ability to establish an uplink/downlink to an airborne platform with a PDA using low-bandwidth iridium satellite communications (SATCOM) and ultra-high frequency (UHF) radio.<sup>9</sup> During this exercise ground personnel were able to "'pull' [and] 'push' data-imagery, signals, intelligence, chat, e-mail [and] other information to and from a network of airborne and ground-based servers, allowing real-time collaboration among users."<sup>10</sup> In practice this makes it possible for fielded troops to download a graphic of the intended landing zone (sent to the PDA by the RPA), allow the receiver to approve or modify the landing zone, and then direct the aircraft to land or perform another action (such as return to base).<sup>11</sup>

## **Autonomous VTOL**

The need for autonomous takeoff and landing capabilities stems from both technical and pilot limitations. Currently, due to bandwidth and data-transfer-rate limitations, RPAs that are not equipped with auto-land capabilities must be remotely piloted to the ground by a pilot or operator within line of sight of the target aircraft.<sup>12</sup> Due to the nature of the proposed operations, having a GCS within visual range of each landing zone (for example on a forward ridgeline or in an urban environment) is not feasible. Furthermore, from a safety perspective, historically approximately 25 percent of US Air Force Predator and Reaper Class A, B, and C mishaps occur from pilot error during the landing phase of flight.<sup>13</sup>

In addition to solving the bandwidth, pilot error, and potential signal jamming and disruption issues, an autonomous takeoff and landing system would also eliminate (or at least reduce) departure delays due to communication, aircrew coordination, and crew rest requirements, thereby increasing mission flexibility. An autonomous VTOL platform utilizing nonoptical sensors would also be able to take off and land in such visually obscured conditions as a sandstorm (or brownout), snowstorm (or whiteout), and complete blackout conditions that would make manned flight extremely hazardous. This is not to say, however, that an aircrew can't assume control or retask the aircraft in flight but simply that it must be able to take off and land without a pilot in direct control.

While fixed-wing aircraft have been using auto-land systems for years, VTOL auto-land systems have taken a few more years to develop. However, in 2000 Bell Helicopter successfully demonstrated the maturity of autonomous VTOL technologies through its Bell Helicopter Textron's Eagle Eye Tactical VTOL RPA. At the Yuma Proving Grounds, Arizona, the Eagle Eye tilt-rotor RPA demonstrator (TR911X) repeatedly and accurately flew a designated route to a "capture point," where it picked up landing instructions, flew a glide slope off of the UAV common automatic recovery system (UCARS) to within 15 feet where it transitioned from forward flight to a hover and then landed within two feet of the target landing point during all 10 attempts (average dis-

tance was less than one foot).<sup>14</sup> The Northrop Grumman MQ-8B Navy Fire Scout is another example of an RPA that is capable of autonomous takeoffs and landings from any surface to include aviation capable warships.<sup>15</sup>

## **Threat and Collision Avoidance**

A significant limitation of current RPAs is their ability to avoid threats. Threats can come in the form of hostile fire (e.g., small arms, antiaircraft artillery [AAA], and surface-to-air missiles [SAM]), natural or man-made obstacles (e.g., terrain, vegetation, power lines, towers, and structures), weather, and other aircraft. To mitigate ground threats, the aircraft can operate at either altitudes or routes outside the effective range/reach of hazards, or it can employ threat detection/avoidance technologies (including countermeasures and threat-avoidance tactics/maneuvers). To avoid other threats, it must employ sense-and-avoid technologies.

Several threat detection and avoidance systems currently are employed on US aircraft. The use of a module or pod equipped with a directional infrared countermeasures system and/or other suppression/countermeasures can help to reduce the risk to the MQ-A in a variety of threat environments. When linked into the flight control system, the aircraft can autonomously execute evasive maneuvers faster than a manned platform. Alternate means of threat avoidance involve flying routes at altitudes that minimize the aircraft's exposure to threats.

For terrain avoidance, an assortment of technologies exists with sense-and-avoid potential hazards. For example, the automatic ground collision avoidance system (Auto-GCAS) continuously monitors the aircraft's performance and position relative to terrain (based upon loaded digital terrain elevation data) and automatically performs a recovery maneuver if the aircraft is put into a position where terrain impact is imminent within a given period. On the F-16, Auto-GCAS provides the pilot with a warning, and then, if the pilot does not take sufficient corrective action, it assumes control of the aircraft and puts it into a safe, wings-level attitude at a pitch necessary to avoid the identified obstacle. Once this flight regime is attained, control is returned to the pilot. During this system's first flight tests

in July–November 1998, it successfully recovered on all 316 test cases (81 recreating past mishaps using flight data recorder data from the mishap aircraft).<sup>16</sup> By May 2006 the system had been tested over 2,200 times with similar results.<sup>17</sup> Auto-GCAS is scheduled to be installed on the US Air Force's Block 40 and later F-16 aircraft starting in 2014.<sup>18</sup>

Wires and other manufactured obstacles present another significant hazard to low-flying aircraft. While difficult to see during daylight, thin wires tend to be virtually impossible to see at night, even with night vision goggles. EADS Defense Electronics' Hellas system is a laser-based system that reliably detects even thin wires at a distance of 1,000 meters. With a laser (which is harmless to the human eye), the system scans the area in front of the helicopter for obstacles. Detected obstacles are then presented in red on a depth and grey-scale image of the terrain in front of the aircraft to enable the pilot to observe and avoid obstacles that might otherwise be struck. This system is already being used by such foreign agencies as the Thai air force and the German federal police.<sup>19</sup>

Hazardous weather conditions present a constant threat to aircraft at nearly all altitudes. Hazardous weather detected by airborne radars can be avoided manually or automatically with weather detection/avoidance algorithms. Other hazardous conditions, such as icing, can be detected with such appropriate sensors as temperature and icing probes. How the aircraft avoids the threat depends upon the mode of operation, the airspace it is transiting, the conditions being encountered, and the aircraft's phase of flight.

While operating in congested airspace (either in the combat AOR or in the national airspace system), the aircraft will need to be able to sense and avoid other aircraft. While traffic collision avoidance systems (TCAS) have been used by aircraft since the 1980s to detect other airborne aircraft, effectively enabling the pilot to take evasive maneuvers, this technology does not detect aircraft that are not transmitting an identification, friend or foe code. These aircraft, as well as those aircraft not transmitting their altitude, cannot be avoided by an automated system based upon TCAS. To counter this limitation, such companies as Boeing, Northrop Grumman, and Defense Research Associates (DRA) are working on sense-and-avoid technologies. While



no systems are currently fully certified and operational, some success has been achieved in this field. For example, DRA, working with the US Air Force, has successfully developed and demonstrated a sense-and-avoid system that can detect small aircraft at distances far beyond the visual range of the human eye. This system uses a combination of optical sensors, processors, and collision-avoidance software to detect intruding aircraft and then warns the pilot of a potential conflict. This system, once fully operational, will enable RPAs to sense and avoid other aircraft and then execute autonomous evasive maneuvers.<sup>20</sup>

### **Autonomous or Semiautonomous Route Creation and Modification**

Currently employed manned and remotely piloted aircraft use an assortment of mission-planning methods to determine the intended route of flight. A majority of current systems use one or more computer programs either to identify or to help identify and/or select a route of flight based upon known restrictions, hazards, or preferences.<sup>21</sup> This route of flight is then loaded into the aircraft's flight-management system either manually or automatically through a data transfer medium. Once in flight the aircraft can be directed to fly the predetermined route automatically (autonomous route following), or it can be modified in flight (semiautonomously) based upon revised information or direction.

As the route of flight selection process is largely automated, a natural question arises: Does the route have to be determined by a person sitting at a computer terminal in a mission-planning facility, or can it be done on, or by, the aircraft? Being able to simply load a set of coordinates or a destination aerodrome ICAO identifier code into an aircraft's flight management system (FMS) (equipped with flight planning software) would eliminate the need for a crew to transfer a route to the aircraft either wirelessly or manually. Such a system would allow for route modification by fielded forces after taking delivery to fulfill changing mission requirements without an in-depth knowledge of the airspace system. A simple "return to base" button would also make it possible for fielded forces to send the aircraft back to its origin by simply pressing a single button (or but-

ton combination). An internal fuel status monitor, similar to those on manned aircraft, should alert the individual modifying the flight plan if an insufficient quantity of fuel exists to perform the directed action. This should take into consideration the weight of the module being transported (either entered manually or calculated by the internal hoist/locking system). This system should also prohibit departure until the condition has been resolved (i.e., the cargo is removed, or the aircraft is given a new location or more fuel).

With respect to en route navigation, current manned aircraft FMSs can also either modify a route of flight to precede directly to a follow-on point or return to a previous route of flight following evasive maneuvers (such as maneuvering around adverse weather or other air traffic). The same holds true for an automated system. This is simply a matter of utilizing an appropriate algorithm for the FMS to apply.

With a system that is capable of generating and flying a self-determined route, the question of full autonomy versus semiautonomy becomes a matter of preference rather than necessity. Such considerations may include the user's level of trust in the system's capabilities, available bandwidth, airspace being transited, and crew member availability. This is not to suggest that a positive control link can't be established so a remote pilot can monitor and redirect the aircraft's flight if required as is currently performed with the US Air Force's R/MQ-1, RQ-4, and MQ-9 aircraft.

## **Automating Manned Aircraft**

While the current manned rotor-wing fleet is unable to fulfill many of the previously identified system requirements (e.g., speed), it has more than proven its ability to perform the tactical airlift mission. As such, one potential option is to modify surplus or existing manned platforms into remotely piloted platforms. Such an approach would take advantage of system capabilities, existing supply/maintenance infrastructures, and personnel familiarity. Exercising this option would also allow the aircraft to be flown manually (assuming the cockpit controls are not removed entirely) should the aircraft be required for a manned mission.

Converting manned aircraft into remotely piloted aircraft dates back to the two world wars when both sides converted

bombers and other aircraft into remotely controlled cruise missiles or guided bombs. Later F-4 aircraft were converted into RQ-4s, but they are currently used as target drones. On 1 December 1984 the Federal Aviation Administration and the National Aeronautics Space Administration (NASA) crashed a remotely piloted Boeing 720 at Edwards AFB to test the fire-retarding capabilities of the FM-9 fuel additive.<sup>22</sup> In December 2007 Boeing and the Air Force Research Laboratory demonstrated that a remotely piloted platform could aerially refuel. While the converted Learjet did not onload any fuel from the KC-135R, it successfully maneuvered autonomously among seven receiver positions that included 20 minutes in the contact position.<sup>23</sup> Other companies are making similar advancements with a variety of technologies for both receiver and tanker RPAs. In all cases the converted aircraft could be flown remotely or manually.

A significant drawback of this approach, however, is that it does not address the extensive wear and tear to which the manned fleet is currently being subjected. Automating the aircraft could conceivably increase operational usage of these platforms without significantly increasing pilot requirements. However, aircraft availability (unless more aircraft are produced or returned to service) and increased maintenance requirements will need to be addressed. It is also conceivable that the additional aircraft usage could result in decreased platform life spans. Even more importantly, currently no platform can fulfill all the aforementioned joint requirements, resulting in some mission requirements remaining unfulfilled.

## **Safety**

Safety is not something that is easily added to an existing system. In fact the best option includes safety considerations in the original design of the aircraft. In so doing, many safety hazards can actually be designed out of the aircraft, making the platform potentially safer than manned aircraft. Arguably the most significant safety concerns surrounding the MQ-A would encompass its propulsion system, obstacle and aircraft collision, lost link, component failure, takeoffs, and landings.

Exposed propeller blades, rotor blades, and jet-engine intakes create a significant hazard to ground personnel operating in the immediate vicinity of a running aircraft. On several occasions ground personnel have been injured (sometimes fatally) after being sucked into a jet engine or encountering a propeller or rotor blade. This includes both on the airport ramp and in the field. Exposed rotor blades have also encountered fixed and mobile obstacles during all phases of operation (startup, taxi, flight, takeoff, and landing) resulting in damage to the aircraft, damage to the object struck, and in some cases injury or death.

To help avoid propeller and rotor-blade contact, several methods can be employed. While in flight, sense-and-avoid technologies will keep the aircraft from known and detected obstacles. While on the ground, the rotor or propeller arc can be maintained well above the heads of personnel who would be operating around the aircraft. However, this does not protect personnel working near an aircraft operating on or next to sloping terrain. The rotor blades can also be shortened, creating a smaller footprint, or enclosed (as in the case of a fan in wing design). An easier, though less safe, design option would be to mark the rotor tips to make the rotor arc visible while in operation.

Adopting a ducted-fan or Fenestron tail rotor design (e.g., RAH-66 and several Eurocopter aircraft) makes the tail rotor not only safer to ground personnel but also quieter, more efficient, and less susceptible to damage (e.g., foreign object damage [FOD] and tail strikes).<sup>24</sup> A no-tail-rotor design, as used on medical helicopters, eliminates the tail rotor. This design uses ducted exhaust air routed through the tail boom to counter torque and aid in directional control.<sup>25</sup> Another way to eliminate the need for a tail rotor is to incorporate counterrotating main rotor blades.

Adopting a ducted-fan-in-wing design would prevent personnel from being exposed to a rotating propeller/rotor by encasing the blade tips and then closing the exhaust louvers when idling on the ground. This design would necessitate, however, the use of a turbo-jet or turbo-fan engine to provide forward flight. The two primary hazards associated with a jet engine are the intake and the exhaust. By mounting the engine atop the fuselage (e.g., RQ-4), the risk of FOD and personnel being sucked into the intake is sig-

nificantly reduced. This design option can also reduce the engine's heat signature from the ground.

Mid-air collisions with other aircraft, terrain, and ground obstacles pose a significant concern for not only remotely piloted aircraft but also manned aircraft. While as of 20 January 2010 the US Air Force had experienced only one mid-air collision between an RPA and a manned aircraft, as more RPAs populate the skies, the risk of mid-air collisions will increase.<sup>26</sup> The use of sense-and-avoid and obstacle-avoidance technologies will help to mitigate this risk.

Lost link is another valid, though less significant, risk to personnel and machine. Before takeoff large RPAs are programmed with a specified mission (to include route) and basic flight rule and contingency information (i.e., what to do when a lost-link condition occurs). While lost-link conditions do occur, the number of mishaps caused by this condition is relatively insignificant. However, several aircraft have been lost due to meteorological conditions (e.g., icing) while executing lost-link procedures/routing (e.g., a pilot was unable to reroute the aircraft around hazardous weather). Designing the aircraft to autonomously operate in compliance with preloaded flight rules and avoid hazards during all phases of flight will eliminate nearly all chances of a mishap occurring due to a lost-link condition. Adding signal boosters and/or signal relay transmitters to other aircraft (e.g., E-3, E-8, high-altitude balloons, etc.) can also help to minimize lost-link occurrences and durations.<sup>27</sup>

A more likely mishap cause would be component failure. As with manned aircraft, aircraft components can and do fail for several reasons during all phases of flight. There have been many instances when a lost-link condition is a symptom, not a cause, of a more significant problem. For example, an electrical failure on the aircraft could result in the loss of its data link as well as other critical systems, eventually leading to aircraft loss. Minimizing the complexity of the aircraft (in design and operation) and having redundant systems will help to mitigate the risk of a mishap occurring due to a single-point failure.

In summary, the utilization of an autonomous VTOL capability would help to eliminate a significant number of manned and remotely piloted aircraft mishaps. As previously discussed, approximately 25 percent of Air Force R/MQ-1

and MQ-9 Class A, B, and C mishaps from September 2001 to January 2010 were due to pilot error during the landing phase of flight.<sup>28</sup> Additionally, at least 70 helicopter mishaps, including 64 fatalities, have occurred in the OIF and OEF AORs alone between September 2001 and December 2009 caused by spatial disorientation and/or visual obstructions (e.g., brownout, whiteout, etc.).<sup>29</sup> Using autonomous VTOL functionality would eliminate human-factor-related RPA landing mishaps. It would also significantly reduce the number of manned aircraft mishaps by providing an alternate means of transport into and out of areas with hazardous conditions. That is not to suggest that this technology would eliminate all takeoff and landing mishaps. It does suggest that pilot error would no longer be a factor. For example, FOD ingestion or uneven landing-zone terrain could lead to a mishap. However, just as technology has matured so that routine and hazardous missions can be accomplished safely and more economically without the human element, landing-zone hazards can also be mitigated through land-force training and/or landing-zone preparation.

### Notes

1. GlobalSecurity.org., "MQ-1B Armed Predator UAV."
2. Other VTOL technologies include ejector fans, tilt shaft/rotor, tilt prop, tilt duct, tilt wing, tilt jet, deflected slipstream, vectored thrust, tail sitters, lift + cruise engines, lift + lift/cruise engines, and tip jets.
3. MQ-18 is the military designation for the Boeing A160T Hummingbird. Another cargo RPA already deployed is the CQ-10A SnowGoose produced by MMIST. See STRATFOR, "US, Afghanistan"; Vogelaar, "Boeing A160T Unmanned Helicopter."
4. GlobalSecurity.org., "Stopped-Rotor Aircraft."
5. During flight tests between 1998 and 2008, the CarterCopter Technology Demonstrator (CCTD) became the only aircraft to achieve  $\mu = 1$  (Mu-1). It has achieved a lift-to-drag ratio of 7 at 150 knots, twice as efficient as the best pure (noncompound) helicopters, and reached altitudes up to 10,000 feet. A new slowed-rotor compound prototype is under construction and is scheduled to fly in mid-2010. A primary objective of this follow-on prototype is to explore the high-speed cruise capabilities offered by this technology (> 250 knots) as well as lift to drag ratios in the 10-14 range. See Jon Tatro, AAI Textron Industries Corporation (director, Advanced Concepts, New Products and Technologies, Unmanned Aircraft Systems), to the author, e-mail, 13 March 2010.
6. Carter, *The CHT Slowed-Rotor/Compound Aircraft*, 22.
7. Bell Boeing, *V-22 Osprey Pocket Guide*, 11.

8. In-wing-ducted fans use engine bleed or exhaust air to power the fan, but the vertical lift is generated using ambient air in the same manner as a traditional helicopter. In May 2009 Northrop Grumman conducted downwash temperature tests of engine exhaust air-powered in-wing-ducted fans and found the fan air temps to be low (unlike the ground temp issues associated with an F-35 or a V-22). Northrop Grumman's ducted fan has turbine blades installed all along its outer perimeter. The exhaust duct leads to a plenum that encloses 140° of the fan circle on the fuselage side. The hot air pushes down through the turbines, losing energy and temperature, and then mixes with the fan air on exit. The vast majority of the air in the fan disk is ambient in temperature as it exits the fan. Since the fan pressure ratio is low, the air is not heated by passing through the fan blades as it is accelerated out. The air then exits, hits the ground, and travels rapidly over it in a skim layer about 10 inches thick. The test data found the peak temps about 6–10 inches above the ground layer and ambient for all the area under the fan. The peak temperatures were found in a C-shaped zone that mimics the shape of the turbine blade plenum around the lift fan (mostly from 150 to 180° F but with the peak along the pod side reaching 250° degrees F). The air that hit the ground never exceeded 150° F with all items in the high-temperature zone remaining safe to touch. While the engines were run from 30 to 45 minutes at a time, aircraft operations would involve only a few seconds of exhaust ground contact during takeoff and landing. No downwash is present while idling on the ground. Ducted-fan aircraft that use vectored thrust from the main engine for vertical lift (such as the AV-8B and F-35) have significantly higher exhaust temperatures.

9. Melnyk, "AMC Industry Day."

10. Stratford, "Northrop Grumman Advanced Information Architecture Concepts"; and Mike Melnyk (director, Fan in Wing Programs, Northrop Grumman), interview by the author, 15 January 2010.

11. Melnyk, interview.

12. Larger RPAs such as the Global Hawk, Predator, and Reaper are typically controlled via satellite uplink with a mission control element in a GCS hundreds or even thousands of miles away via satellite uplink. The time lag to transfer system information and video feed from the UAV to the satellite and then on to the GCS for display creates a several-second time lag between perceived condition and position and actual condition and position. This is further amplified by the fact that any pilot inputs take an equivalent amount of time to travel back to the aircraft for processing and action. The entire time lag between data transmission and pilot direct input receipt can take several seconds. While insignificant at cruise altitude, a time lapse of a second or two can mean the difference between a successful landing and a crash. Further complicating matters is the possibility of a lost-link condition due to an assortment of causes including, but not limited to, terrain, malfunction, scintillation, and mechanical failure.

13. See AFSAS, Class A, B, and C mishap data, 13 January 2010. While the RQ-4 Global Hawk uses an autonomous takeoff and landing system, US Air Force Predator and Reaper aircraft have no such capability. This deficiency has led to a significant number of mishaps during these phases of flight. From September 2001 to January 2010, 22 percent of the

Predator and Reaper Class A, 45 percent of the Class B, and 25 percent of the Class C mishaps were due to pilot error during the landing phase alone. DODI 6055.7 offers the following definition for DOD mishaps.

Class A: The resulting total cost of damages to Government and other property in an amount of \$1 million or more; a DOD aircraft is destroyed; or an injury and/or occupational illness results in a fatality or permanent total disability. Class B: The resulting total cost of damage is \$200,000 or more, but less than \$1 million. An injury and/or occupational illness results in permanent partial disability (Table E7.T1. of enclosure 7); or when three or more personnel are hospitalized for inpatient care (which, for accident reporting purposes only, does not include just observation and/or diagnostic care) as a result of a single accident. Class C: The resulting total cost of property damage is \$20,000 or more, but less than \$200,000; a nonfatal injury that causes any loss of time from work beyond the day or shift on which it occurred; or a nonfatal occupational illness or disability that causes loss of time from work or disability at any time (lost time case).

See DODI 6055.7, *Accident Investigation, Reporting, and Record Keeping*, 3 October 2000, 3.

14. Helis.com, *Bell Eagle Eye*; and Bell Helicopter, *Eagle Eye Pocket Guide*, 7.

15. Naval-Technology.com, "Fire Scout VTUAV"; and Northrop Grumman, "MQ-8B Navy Fire Scout."

16. Mapes, Auto-GCAS.

17. Defense Oversight Council Aviation Safety Improvements Task Force Safety Technology Working Group, *Fighter/Attack*.

18. Surowitz, USAF ACC/SEF, to the author, e-mail, 10 March 2010. Auto-GCAS is scheduled to be installed on F-16 Block 40/42/50/52 aircraft only.

19. *Air Force News*, "EADS and DRS to Develop Helicopter Obstacle Warning Systems," 26 June 2007.

20. Defense Research Associates, "Sense and Avoid."

21. Hazards may include weather, ground threats (e.g., AAA and SAMs), terrain, and dense airspace.

22. Horton and Kempel, *Flight Test Experience*, 4, 16.

23. Boeing, "AFRL, Boeing Demonstrate That UAVs Can Perform Automated Aerial Refueling."

24. Absolute Astronomy, "Tail Rotor"; and Aerospace Web, "Fenestron Tail Rotor."

25. Aerospace Web, "Fenestron Tail Rotor."

26. See AFSAS, 20 January 2010. The mishap involved an RQ-4 on final approach and an HH-60 on initial climb out.

27. Such high-altitude balloons as those built by Aerostar can achieve altitudes of over 128,000 feet carrying loads in excess of 5,000 lb. NASA has also demonstrated the ability to maintain an altitude of 110,000 feet for up to 100 days. High-altitude balloons have also been successfully tested with communication relay and imagery payloads. See Terdiman, "NASA Tests Super-High-Altitude Balloon"; NASA, "Wallops Flight Facility Goddard Space Flight Center Flight Summaries for FY08"; Rupar, Doffoh, and Mereish, "High Altitude Relay and Router," 2007 NRL Review, 165-67.



28. Air Force Safety Automated System (AFSAS), Class A, B, and C mishap data, 13 January 2010.

29. Ibid.; US Naval Safety Center, *Class A Mishap Data*; and US Army Safety Center, *Class A, B, and C Mishap Data*. Thirty-six of the 55 US Army mishaps (resulting in 47 fatalities) involved cargo- and troop-carrying aircraft. The remaining mishaps involved OH-58s and AH-64s. The overall spatial disorientation and visual obstruction mishaps for the Air Force, Army, and Navy/Marine Corps equaled 70 mishaps and 64 fatalities.

## Chapter 4

### **Proposed Solution**

As any solution depends on the problem it is intended to solve, so must the design of the MQ-A. It must also be provided within a specific context based upon accepted norms and/or assumptions.

### **Assumptions**

With this backdrop in mind, the conceptual solution proposed in this chapter will be based upon the following assumptions:

1. The joint MQ-A requirements outlined in chapter 2 remain valid and unchanged.
2. Future operating environments will be similar to current operating environments regarding FOB accessibility (i.e., a significant number of troop formations will be inaccessible to fixed-wing resupply aircraft except with regards to airdrop or roads).
3. Commanders will primarily utilize the MQ-A for cargo movement and not for troop transport except where noted in this section.
4. The US Air Force and US Army will not field any additional aircraft models not currently employed in OIF and OEF (with the exception of the C-27) for airlift. This is not to say the number of aircraft currently employed will remain fixed (e.g., the number of some rotor-wing assets may increase or decrease based upon aircraft availability and mission requirements).
5. Technologies discussed in this study are not proprietary and thus can be combined into a joint platform (e.g., a Northrop Grumman aircraft can employ a Bell auto-land system and a Boeing sense-and-avoid sensor package).
6. Current service employment concepts (and subsequent supply requirements) will remain largely unchanged.

7. MQ-A assets will be apportioned to the joint force by the joint force commander (JFC) and employed based upon the needs of the receiving functional commander.

## **MQ-A Description**

After considering the aforementioned joint MQ-A requirements and the current and emerging technologies, the study proposes the following aircraft characteristics for consideration (a concept of employment will be presented in chapter 5).<sup>1</sup> The MQ-A will be equipped with a turbo-fan-driven, in-wing-ducted-fan propulsion system capable of VTOL and forward velocities in excess of 300 knots. To avoid most ground threats and to achieve a greater range, the MQ-A will be able to achieve an altitude of at least 30,000 feet. Later, while in a tactical environment, the MQ-A will be able to cruise at altitudes as low as 50 feet with autonomous terrain-mapping, terrain-avoidance, and threat-avoidance software. With a payload of approximately 3,000 lb., it will be able to achieve an operational radius in excess of 500 nautical miles with enough fuel to return to base once the cargo is downloaded. To extend its transit range, the MQ-A will be able to replace its operational cargo module with an extended range fuel module and to fly at its maximum or optimum cruise altitude.

To legally operate in the en route structure, the MQ-A will be equipped with the required NAS and ICAO navigation and communication equipment. This equipment will include area navigation/vertical navigation certification; very high frequency, UHF, high frequency, and SATCOM communication/navigation systems; Mode C and Mode S transponders; sense-and-avoid technologies; and the option to attach a manned pilot/passenger module (not necessarily pressurized).

While in flight the MQ-A will be able to operate autonomously but will be operated semiautonomously by a pilot and a sensor operator. Destination coordinates will be loaded into the onboard FMS by a ground operator or remotely by an aircrew in a GCS. The route will be determined by the aircraft's onboard mission planning software,

by mission planning software in the GCS, or manually by flight crew or ground personnel. Selected hazard-avoidance routes will consider terrain, obstacles, operating flight rules/restrictions, and known threats. During the flight the aircrew in the GCS will be able to assume control and either reroute the MQ-A or manually fly the aircraft. Onboard hazard sense-and-avoid sensors, including terrain, obstacle, and aircraft sensors, will alert the aircraft and monitoring aircrew of approaching hazards. If the monitoring aircrew fails to take corrective action, the aircraft will perform evasive maneuvers autonomously. Once the threat has been avoided, the aircraft will return to its previously designated mission.

When approaching its designated landing point, the MQ-A will power up the in-wing-ducted fans and slow to a nose level hover at a predesignated altitude over the predesignated landing zone. Using a PDA linked to the aircraft, the fielded forces can then approve the landing, adjust the landing point, direct the aircraft to hold, send the aircraft to its next destination, or direct it back to base. If the coordinates are not known or the landing zone is a moving target, such as on the back of a ship, a small short-range landing-zone marker beacon/transmitter can be placed at the center of the intended landing zone and activated. Once instructed to use the marker, the aircraft will assume a position over the beacon and commence the vertical landing while maintaining its relative position over the marker. If a landing point is not acknowledged by the ground personnel, the landing decision will be deferred to the monitoring GCS crew. If a link is lost during the landing-zone acquisition and approval phase, the aircraft will perform a predetermined function to (1) hold to await further instruction, (2) proceed to the next waypoint, (3) land at the preloaded coordinates, or (4) return to base. The selected action will depend upon preloaded algorithms and/or the anticipated security of the intended landing zone.

Once approved for landing, the MQ-A will perform an autonomous vertical descent by using onboard global positioning system (GPS)/inertial navigation system (INS) and thrust vectoring (using the ducted-fan louvers) to maintain a position directly over the intended landing position. This procedure will allow the aircraft to land in a confined area

without the ground personnel designating an approach corridor. It will also minimize side-loading strains on the landing gear during landing and reduce the chances of a landing roll.

To help minimize the chances of aircraft roll over while landing on an uneven surface, the aircraft will be equipped with four retractable landing-gear struts located at the forward and aft corners of each wing. The gear struts will place the aircraft fuselage (minus the mission module) and wings at least six feet above the ground to avoid potential damage due to small obstacles such as stumps and debris and to make it possible to walk and operate under the aircraft easily. Dual wheels on each strut (which auto lock after a predetermined roll distance upon landing) will allow the aircraft to assume a stable four-point footing and minimize potential negative mission impact should a tire fail. Manually releasing the auto-lock system will allow the aircraft to be pushed or to be pulled to a desired load, unload, or launch point.

While the ducted fan is powered by jet-engine exhaust air, vertical lift is provided by drawing ambient air from above the wing and blowing it down at exhaust temperatures below 100° C. To help ensure the safety of ground personnel operating under and around the aircraft, the ducted-fan louvers will remain closed while the aircraft idles on the ground. In this configuration, all jet exhaust will be ducted aft of the aircraft through the normal jet exhaust system. While maneuvering in flight or on the ground, variable thrust and the ducted-fan louvers will redirect fan exhaust as required to affect pitch, roll, yaw, and taxi directions. The engine will be positioned on the top of the fuselage to minimize hazards to ground personnel and to reduce the risk of foreign object damage to the engine.

When the offload and/or onload is complete, ground personnel will either enter new destination coordinates (with an optional route of flight) into the aircraft's FMS or select (1) to return to base (point of origin) or (2) to continue to the next en route stop. A microphone and speaker system with a direct link to the monitoring GCS will be located adjacent to the FMS input panel to facilitate communication between the ground personnel and the monitoring/controlling aircrew should mission changes or coordination be required.

Once the takeoff command is received from ground personnel or the GCS, the aircraft will idle for a designated period (approximately 20 seconds) to give time for ground personnel to move to a safe distance from the aircraft and to minimize the time the aircraft is exposed to hostile fire in a combat situation. The MQ-A will then open the ducted-fan louvers, power up the ducted fans using engine exhaust air, and increase power and takeoff capability autonomously. To minimize the chances for mishaps, all takeoffs and landings will be performed autonomously. Once a safe altitude is achieved, the MQ-A will transition to forward flight, disengage the ducted fans, close the louvers, and use the centerline thrust turbo-fan jet engine for en route flight.

To change taskings, mission modules can be interchanged and attached to wing and fuselage hard points. To assist with the changing, loading, and unloading of the primary fuselage module, the MQ-A will be equipped with an internal hoist system that can be operated from an externally accessible control panel. While the module is in the up configuration, electrically powered latches will be engaged to ensure the module remains attached to the aircraft during flight. The latch system will calculate the pod weight and adjust fuel calculations accordingly. An electronic umbilical cord will attach to the module to provide two-way communication between the module and the MQ-A. Non-proprietary mission modules will include, but are not limited to, the following:

1. Cargo
2. Modular airdrop
3. Small package airdrop
4. ISR, with an extended-range fuel bladder
5. ISR, with a multiple-ejector ordnance rack
6. ISR, with an extended sensor suite
7. Side scan radar with uplink to a manned reconnaissance platform or a ground control station
8. Extended-range fuel bladder

9. Manned pilot module with a cargo bay (capable of single litter medical-evacuation or dual-passenger transport)
10. Combat search and rescue capability
11. Communication relay suite<sup>2</sup>

As the MQ-A will perform all takeoffs and landings autonomously and fly most en route segments autonomously, the aircraft will be able to operate in conditions that would otherwise be considered hazardous for manned aircraft. Using a radar altimeter, GPS/INS position awareness, beacon homing, rapid automatic corrections, and sense-and-avoid technologies, the aircraft will be able to perform VTOL in all weather conditions (e.g., whiteout, brownout, and high winds) and throughout the day without the risk of the pilot suffering from spatial disorientation or visual illusions.

Hazardous weather conditions such as icing and thunderstorm activity will be avoided by using aircrew flight-path monitoring and onboard weather sensor equipment. If icing conditions cannot be avoided during takeoff or landing phases of flight, the aircraft's anti-ice system is equipped to handle short flights in moderate icing. With the assistance of terrain mapping and precision course management, the MQ-A will be able to operate in mountains and canyons even with restricted visibility. The MQ-A will also be able to operate in a CBRNE or a hostile environment where commanders may not wish to send manned aircraft. When the aircraft is unable to operate independently of aircrew, the MQ-A will not need to wait for an aircrew to use the aircraft. This procedure will make on-demand, depot-to-foxhole resupply a reality 24/7.

Powering the ducted-fans with engine exhaust air through valve-controlled internal ducting instead of an auxiliary drive shaft will help to minimize aircraft weight and maintenance. It will also minimize the potential for engine damage if something is sucked into a wing fan (even if the object stops the fan). Replacing typically hydraulic systems with electrically controlled and actuated aircraft systems (i.e., brakes, flight controls, and valves) will minimize servicing requirements and improve survivability. Light

composite materials will help to minimize weight while maximizing payload, range, and endurance.

To assist with transport beyond the aircraft's extended operating range, the aircraft can be rapidly disassembled and transported in standard ship containers or on board a C-17 or a C-5. Mission modules can be transported individually or in specially designed module transport containers.

### **Notes**

1. Several companies have working or proposed solutions to the problems presented in this document. While some solutions, including Boeing's A160T Hummingbird, already have been unveiled to the public, several others are still behind closed doors—at least for the time being. The solution presented in this chapter draws upon existing, mature, or nearly mature technologies for working and proposed platforms that need only to be combined into a single system. Proprietary system-specific information has been omitted from this study to protect the rights of the companies that provided the research materials.

2. Due to the specialized ISR mission and its associated extended persistence requirements, unless wing extensions are added to the MQ-A to effectively increase the ground footprint, it is highly unlikely that the MQ-A will be able to compete with existing dedicated ISR RPAs with respect to persistence. While range and speed may partially offset this limitation, the MQ-A should be seen as an ISR augmentation platform when demand exceeds platform availability and not as a replacement for existing or future specialized ISR RPAs. The MQ-A's primary role should remain focused on the movement of material in the tactical environment (e.g., cargo, munitions, and possibly personnel).





## Chapter 5

### **Synopsis of Concept of Employment**

This concept of employment (CONEMP) synopsis provides a brief overview of how the MQ-A unmanned intra-theater airlifter will operate in support of US joint forces across the full spectrum of military operations. Refer to appendix 4 for a complete version of the CONEMP.<sup>1</sup>

### **Overview**

As no single service has been identified to operate the MQ-A, two primary scenarios exist regarding MQ-A employment: (1) a single service is the sole employer of the MQ-A, and (2) the MQ-A is employed as a joint aircraft with multiple services integrating it into their respective logistical infrastructures. The MQ-A will augment current airlift aircraft as they are used by the DOD with a focus on TS and MC cargo movement while maintaining an ability to perform several other missions when and where required. Joint training and doctrinal and procedural commonalities among the services will help to ensure full integration of deployed units into the existing logistical systems.

### **Organization**

The MQ-A's multirole capabilities make it an essential component of the joint force commander's capabilities. Structuring MQ-A units as self-sufficient, semiautonomous, expeditionary units will optimize these units for future operations. The JFC will allocate MQ-A units (hereafter referred to as expeditionary airlift squadrons [EAS]) after they are deployed to supported commanders to help fulfill tactical airlift requirements with an emphasis on same-service support. To help ensure mission flexibility, the supported commanders will exercise tactical control (TACON) over the EAS with operational control and administrative control remaining with the EAS's service component commander.

Mission planning and coordination will be enhanced by collocating the EAS with the supported unit whenever pos-

sible. In cases where the EAS is not collocated with the supported unit, the EAS will provide a liaison officer to the supported unit to ensure proper coordination and asset utilization. EASs will coordinate TS/MC missions directly with the supported unit. Each service will also provide liaison officers to the combined air operations center (CAOC) to coordinate tactical airlift requirements. EASs and supported units will also provide representation to the joint planning and execution cells to help ensure efficient and maximum utilization of available resources.

## **Intelligence**

Acquiring timely and accurate intelligence information is essential to the successful execution of deployed operations. This acquisition is particularly critical in a tactical environment to ensure that mission planners and aircrew can safely and effectively employ assigned assets with minimal risk to friendly forces and equipment. Tactical intelligence will be provided to aircrew and mission planners by theater intelligence personnel assigned to the supported commander before mission execution and to commanders upon request. Relevant intelligence information will be pushed to all applicable parties before, during, and after mission execution or as appropriate.

Intelligence research, analysis, and dissemination will be provided in accordance with the supported command's applicable guidance (i.e., doctrine, procedures, and instructions). Emphasis will be given to threat identification and analysis. Intelligence personnel assigned to the EAS will provide supplemental information and will assume primary threat/risk assessment responsibilities if assistance is unavailable from the supported unit. Under TACON the supported unit commander is granted risk-acceptance authority.

## **Operations**

While an EAS is allocated to a supported commander to enhance cooperation and effectiveness, general flight operations will be conducted in accordance with the EAS's service guidance. Each service will also maintain waiver authority over its deployed assets, but risk acceptance will be

delegated to the supported commander to help ensure maximum flexibility and responsiveness to changing operational requirements. It is also understood that the remotely piloted nature and the autonomous capabilities of the MQ-A may lend themselves to a higher risk acceptance level. Significant differences in the guidance governing the employment of RPA air assets will need to be resolved among the supported and supporting commanders before asset employment.

The MQ-A's autonomous VTOL and all-weather capabilities make it an ideal platform to conduct a wide range of missions in extremely hazardous conditions.<sup>2</sup> Simplistic launch and recovery procedures further enhance mission flexibility and responsiveness. To launch the aircraft, ground personnel either will enter the coordinates or identifiers for the next destination into the onboard FMS or select one of two options that include (1) return to base (point of origin) or (2) continue to the next en route stop. The desired route of flight can be loaded manually into the aircraft's FMS or remotely from the GCS. If a route of flight is not entered, the FMS will compute a route of flight based upon known airways, threats, terrain, and airspace restrictions.<sup>3</sup> Once a takeoff command is received from ground personnel or from the GCS, the aircraft will give ground personnel a designated period to clear the immediate area before engaging the VTOL propulsion system. The in-wing-ducted fans then will power up and perform an autonomous vertical takeoff, climb to a safe altitude, and transition to forward flight. While the aircraft is en route to a destination, the route may be changed remotely by the GCS or autonomously to avoid hazards identified using a series of onboard weather, ground threat, terrain mapping, and obstacle-detection sensors.<sup>4</sup>

When approaching the predesignated landing point, the MQ-A will descend to a predesignated altitude and enter a hover over the designated landing point. The fielded forces, using a PDA linked to the aircraft, then will accept the landing point, adjust the landing point, direct the aircraft to hold, send the aircraft to its next destination, or direct it back to base. The aircraft can also be instructed to land on a small, portable, short-range marker beacon/transmitter if exact landing coordinates were not loaded into the aircraft before arrival. If a landing point is not acknowledged by ground personnel, the landing decision will be deferred to

the monitoring aircrew. For aircrew unavailability or a lost-link condition, the aircraft will perform a predetermined function that includes instructions to (1) hold for further instructions; (2) proceed to the next waypoint; (3) land at the designated coordinates/marker; or (4) return to base. The selected action will depend upon preloaded algorithms and/or the anticipated security of the intended landing zone.

Once approved for landing, the MQ-A will perform an autonomous vertical descent to landing using onboard GPS/INS systems and thrust vectoring (via ducted-fan louvers) to maintain a position directly over the intended landing position throughout the descent. This procedure will allow the aircraft to land in a confined area without ground personnel designating an approach corridor to avoid ground obstacles. Performing a controlled vertical landing also will help to minimize side-loading strains on the landing gear, and auto-locking brakes will help to reduce the chances of a landing roll. For ship operations, a crew monitoring the aircraft's progress will assume control, fly it to the target ship, lock the aircraft to the mobile marker beacon/transmitter, and direct the aircraft to land. The MQ-A then will assume a position over the marker and perform a vertical landing onto the deck.

Many of the mission profiles flown during contingency operations have a direct application to military operations other than war and thus will be flown in the same manner. For example, the movement of cargo from a FOB to fielded troops 200 miles away over rough terrain is relatively the same mission as moving supplies from a supply hub to fielded forces, a nongovernmental organization, or an intergovernmental organization over unsafe roads during a humanitarian assistance mission. The aircraft's airdrop capabilities enable it to supply locations with unsuitable landing zones, and the ISR modules can provide for a persistent around-the-clock ground surveillance in a border patrol, operating area, or search-and-rescue role.

## **Logistics/Sustainment**

A movement control team (MCT), provided by the supported unit, will perform all arrival/departure airfield control group (A/DACG) operations, including cargo and pas-

senger handling, at the supporting EAS's main operating base. To help expedite the loading and unloading process at locations not serviced by an MCT, supported commanders shall ensure that all supported personnel are trained on basic aircraft operation (i.e., load, unload, and launch). Cargo and passenger load information will be centrally tracked by the MCT through established service logistical tracking systems. Where access to these systems is not available, cargo and passenger manifest data will be logged at the first suitable location.

When practical, excess capacity will be released to the Air Mobility Division in support of the common user airlift pool. Load requirements will be submitted in accordance with the Gulf Cooperation Council procedures and priorities. Common user movements will be monitored by the Air Mobility Division's deployment and distribution operations center and will not take precedence over TS/MC requirements.

Normal aircraft maintenance will be conducted by the EAS and assisted by the supported unit. Data/forms management will be conducted through the EAS's service-approved maintenance information systems. During deployed operations, maintenance personnel will perform actions consistent with day-to-day flying activities. Extended heavy maintenance and scheduled inspections and above may be conducted at a designated heavy maintenance location. A home station check equivalent may be conducted in theater. The aircraft will deploy with a minimum logistics manning package, supply assets (i.e., mobility readiness spares packages), and support equipment capable of sustaining 24/7 operations for an initial 30-day period. Additional equipment will follow via strategic movement in the most expedient manner possible and will arrive no later than 30 days from initial employment. The logistics/maintenance unit will be equipped and manned accordingly.

All other sustainment for the EAS will be provided by the supporting service except for theater support normally provided to the other services by doctrine, DOD directive, JFC directives, or other intraservice support agreements. Base operating support agencies will coordinate and assist in formalizing memoranda of understanding/memoranda of agreements as required.

## **Communications/Navigation**

Regardless of the type of mission conducted, the MQ-A will be required to operate in domestic, international, and contingency/military airspace. In all cases, flight planning and mission execution will be conducted in accordance with applicable airspace requirements. In some cases, restrictions by the air route traffic control center on RPA activities within its airspace can be avoided with a manned pilot/passenger module. Regardless of the mode of operation, procedures, restrictions, and requirements applicable to the airspace being transited will be complied with. Failure to have all required communication and navigation systems may result in restrictions or denial of airspace entry. Flights in military-controlled airspace shall be conducted in accordance with local operating procedures.

Bandwidth limitations can also significantly affect mission effectiveness and the number of platforms that can operate in a given area. To help minimize bandwidth usage in a bandwidth-limited environment, autonomous operations will be conducted to the maximum extent possible with only basic aircraft status information (e.g., systems condition and position) being transmitted to the GCS during noncritical phases of flight. Direct line-of-sight data transmission to end users and relays through other network-centric platforms will also help to minimize satellite bandwidth usage.

Several hostile activities, environmental factors, and mechanical failures can result in lost link with the controlling or monitoring GCS. In addition to signal-protection operations, all flights will be launched either with a full flight plan loaded or with emergency routing that will be followed when a lost-link condition occurs. Due to the aircraft's autonomous capabilities, the former option is preferred to minimize negative mission impacts should satellite connectivity be lost. However, during missions that require semi-autonomous operations, a bingo point will be determined so that the mission will be aborted or modified if the communication link with the GCS is lost. In no cases should a lost-link condition result in loss of control of the aircraft and/or subsequent system/aircraft loss.

## **Legal**

Disciplinary and *Uniform Code of Military Justice* authority will remain with the service member's service component commander.

### **Notes**

1. While the CONEMP assumes the employment of a platform that meets the criteria proposed in chapter 4, a majority of the guidance presented in this CONEMP can be applied with minor modifications to other RPA VTOL platforms.

2. Adverse weather or environmental conditions such as low-cloud cover, fog, blackout, whiteout, and brownout have limited to no impact upon MQ-A operations. The GPS/INS, stabilization instrumentation, radar altimeter, and obstacle/hazard sense-and-avoid technologies make it possible to operate the aircraft without visual cues. Furthermore, as the platform is remotely piloted (unless using a pilot/passenger module), the aircraft can operate in a CBRNE environment without risk to crew members.

3. Autonomously determined routes should be verified by qualified aircrew before departure. Unverified routes should only be used in military-controlled airspace with special consideration given to en route altitudes.

4. The integration of GPS/INS, weather radar, a DIRCM pod (or equivalent), auto-GCAS, and sense-and-avoid technologies enables the MQ-A to detect and ultimately avoid both ground and airborne threats and hazards. This sensor suite enables the MQ-A to operate everywhere between an extreme low-level altitude up to its maximum operating altitude of over 30,000 feet in limited-to-no-visibility conditions.





## Chapter 6

### **Conclusion**

Existing, proven, and rapidly evolving technologies present the DOD with a unique opportunity to significantly enhance current tactical airlift capabilities without significantly increasing cost or carbon footprint. What is needed is a paradigm and concept of operations shift.

### **Recommendations**

The current operational environment has driven a need for increased tactical airlift, a need that cannot be completely fulfilled with existing airlift assets. Rather than increasing the manned tactical airlift fleet, the DOD should augment the current joint fleet with remotely piloted cargo platforms capable of autonomous and semiautonomous operations into routine and hazardous operational environments. Furthermore, service and joint doctrine should be modified to fully incorporate these remotely piloted platforms in all military operations.

Presently, tactical airlift is accomplished by manned platforms at an operational cost to normally supported ground forces. Many of these missions, particularly routine and extremely hazardous missions, can be accomplished by remotely piloted platforms with minimal to no risk to aircrew or ground personnel, thus freeing manned assets for other missions. Augmenting the existing manned tactical airlift fleet with a remotely piloted platform capable of autonomous and semiautonomous operations would provide a means to dramatically increase intratheater airlift capacity, efficiency, aircrew safety, responsiveness, and flexibility while minimally increasing, or possibly even decreasing, overall carbon footprint and costs. In so doing, the MQ-A will decrease the need for ground convoys and contract ground and air carriers.

Considering the tactical airlift requirements established by each of the services (summarized in chap. 2), chapter 4 offers recommendations for the characteristics of a future unmanned intratheater airlifter. The concept of employment

presented in chapter 5 further explains the functionality of the MQ-A platform and proposes a concept of employment for service consideration. However, recognizing other multiple options that can meet the established requirements, it is essential that the MQ-A be designed to fulfill most, if not all, of the tactical airlift needs of each service.

## **Aircraft Characteristics**

Regardless of the form the MQ-A assumes, it must address the needs of the services with several key characteristics. The MQ-A must be modular in design and be capable of fulfilling a wide assortment of missions depending upon the module attached. The basic air frame must be capable of autonomous and semiautonomous operations while en route and autonomous VTOL in all weather conditions and levels of satellite reception degradation. It should also be able to operate at altitudes and speeds comparable to jet aircraft while transporting up to 3,000 lb. of cargo at least 500 nautical miles.

To ensure maximum mission flexibility and responsiveness, ground personnel must be able to monitor and alter the mission profile when and where required. Ground personnel should also be able to communicate with the controlling GCS both during flight operations and during loading/unloading. To enhance deployability, the MQ-A should be self-deployable and/or transportable via current strategic lift assets.

During all phases of operation, the MQ-A must present a minimal risk to ground personnel. While idling on the ground, the aircraft should minimize risk to ground personnel operating in the immediate vicinity. It should have low exhaust temperatures, an internal hoist system to lift modules, a significant ground clearance, and minimal to no chance of propeller or rotor-blade contact. While in flight, redundant systems should prevent system failure or loss of aircraft control following a single-point failure.

To maximize operating areas, the MQ-A must be capable of landing in confined and shifting landing zones. In addition to being able to land on a fixed coordinate, the aircraft must be able to lock onto and land on a small, mobile landing-zone beacon/transmitter with a high level of accuracy. This will include landing on aviation-capable warships.

## **Summary**

The challenging operational environments that we now face make airlift a greater necessity than ever. Conventional, counterinsurgency, and military operations other than war require the movement of supplies to isolated, perilous, and in some cases congested areas over insecure lines of communication. While airdrop technologies are improving, their inability to service some locations accurately, reliably, inexpensively, and without a requirement to extract airdrop materials demands the use of VTOL assets in hazardous conditions. Unfortunately, however, insufficient manned assets currently exist to service these urgent requirements while still fulfilling their primary missions of troop movement support.

The RPA offers an inexpensive, safe, reliable, flexible, and responsive means to keep forward troops supplied in all conditions and environments. It also offers a means to reduce ground convoy requirements, supports intratheater/intraship cargo movement, supports rapidly advancing troops, and supplies government and nongovernment organizations during humanitarian assistance and disaster response missions. Employed in sufficient quantities, it also offers the potential for a reduced manned airlift footprint. Existing and rapidly maturing technologies offer an opportunity to develop a multirole, modular platform capable of fulfilling each service's tactical supply needs. While a shift to tactical airlift utilization may require a paradigm and doctrinal shift, a significant opportunity exists to increase intratheater airlift capacity, flexibility, and responsiveness without significantly increasing carbon footprints, costs, or risk to manned aircraft and their crews.



## Appendix 1

### Contract Lift Configurations

This document provides an abbreviated summary of lift assets currently employed in support of OEF and OIF. These lists are not all-inclusive, and operating costs are subject to change. The C-17 data has been added for comparison purposes only.

Short Takeoff and Landing (STOL) Lift Configurations						
A/C Type (cost/hr)	Max Takeoff Weight (pounds)	Max Range (nautical mile [nm])	Pax	Cargo Max (pounds)	Service Ceiling (feet [ft])	Lift-to- Drag Ratio (L/D) (ft)
Casa 212 (\$3,906)	17,600	777	20	6,200	25,000	984
Metro (\$4,179)	16,500	1,150	19	5,600	25,000	2,400
C-130J (\$5,005)	164,000	2,100*	128	44,000	28,000	1,500
Dash 8 (\$5,015)	34,500	1,065	37	7,500	25,000	2,979
C-130 H (\$7,573)	155,000	1,300*	92	42,675	33,000	2,130
C-17 (\$6,662)	585,000	2,400**	102	170,900	45,000	-
Casa 235 (\$8,427)	36,300	2,700	45	13,200	30,000	1,979

\*with 35,000 lb. payload

\*\*with 169,000 lb. payload



## Appendix 2

### **John Warner National Defense Authorization Act for Fiscal Year 2007**

#### **SEC. 941. DEPARTMENT OF DEFENSE POLICY ON UNMANNED SYSTEMS.<sup>1</sup>**

(a) **POLICY REQUIRED.**—The Secretary of Defense shall develop a policy, to be applicable throughout the Department of Defense, on research, development, test and evaluation, procurement, and operation of unmanned systems.

(b) **ELEMENTS.**—The policy required by subsection (a) shall include or address the following:

(1) An identification of missions and mission requirements, including mission requirements for the military departments and joint mission requirements, for which unmanned systems may replace manned systems.

(2) A preference for unmanned systems in acquisition programs for new systems, including a requirement under any such program for the development of a manned system for a certification that an unmanned system is incapable of meeting program requirements.

(3) An assessment of the circumstances under which it would be appropriate to pursue joint development and procurement of unmanned systems and components of unmanned systems.

(4) The transition of unmanned systems unique to one military department to joint systems, when appropriate.

(5) An organizational structure for effective management, coordination, and budgeting for the development and procurement of unmanned systems, including an assessment of the feasibility and advisability of designating a single department or other element of the Department of Defense to act as executive agent for the Department on unmanned systems.

(6) The integration of unmanned and manned systems to enhance support of the missions identified in paragraph (1).



(7) Such other matters that the Secretary of Defense considers to be appropriate.

(c) CONSULTATION.—The Secretary of Defense shall develop the policy required by subsection (a) in consultation with the Chairman of the Joint Chiefs of Staff.

(d) REPORT.—Not later than 120 days after the date of the enactment of this Act, the Secretary shall submit to the congressional defense committees a report containing—

(1) the policy required by subsection (a); and

(2) an implementation plan for the policy that includes—

(A) a strategy and schedules for the replacement of manned systems with unmanned systems in the performance of the missions identified in the policy pursuant to subsection (b)(1);

(B) establishment of programs to address technical, operational, and production challenges, and gaps in capabilities, with respect to unmanned systems; and

(C) an assessment of progress towards meeting the goals identified for the subset of unmanned air and ground systems established in section 220 of the Floyd D. Spence National Defense Authorization Act for Fiscal Year 2001 (as enacted into law by Public Law 106–398; 114 Stat. 1654A–38).

(e) UNMANNED SYSTEMS DEFINED.—In this section, the term “unmanned systems” consists of unmanned aerial systems, unmanned ground systems, and unmanned maritime systems.

#### **Note**

1. US House, *John Warner National Defense Authorization Act*.

## Appendix 3

### Service RPA Requirements

Requirement	USMC UNS/MCWL	Army JMR	USAF Air Mobility Command
<b>Transport &amp; Storage</b>	20 ft TEU ISO containers	Inside C-17 with minimal disassembly	Not defined
<b>Ship Operations</b>	Amphibious, small footprint	Amphibious, small footprint	Ship-based/recoverable capable
<b>Assembly &amp; Operation</b>	Quick assembly by Marines	Quick assembly	Not defined
<b>Radius @ 1600 lb. Payload</b>	35 nm offshore, 250 nm inland/75 nm from 12K density alt	254 nm, 0.5 hr on station cargo, 2 hrs ISR/attack	500 nm (can reduce payload to 500 pounds)
<b>Cargo Carriage</b>	Internal & external, no handling equip at delivery	Internal & external	Not defined
<b>Speed</b>	>250 knots (kts)	>170 kts	> 250kts
<b>Payload</b>	1,600 pounds, at least 4 drops per mission/750 pounds at 12K density altitude	Not defined	500–3,000 pounds
<b>Operations</b>	Autonomous, land via Soldier signal, beacon or at preset LZ	Autonomous, collision avoidance, contingency management	Autonomous, reuseable, flotation capable
<b>VTOL Landing Footprint</b>	Small, small for ships, urban ops, roads, FARPS & FOBs, unprepared surfaces	Small, small for ships, urban ops, roads, FARPS & FOBs, unprepared surfaces	Unprepared surface landing capable, 300 ft short takeoff and landing acceptable
<b>VTOL Ops Altitudes</b>	12K density (750 pounds, 75 nm radius RFP)	6K 95 deg	Not defined
<b>Protection</b>	Not defined	Small arms, large caliber AAA, CBRN	Not defined
<b>O&amp;M</b>	Reliable & low maintenance hrs/ft hr, “flying truck”	Rugged, reliable	Not defined

<b>Requirement</b>	<b>USMC UNS/MCWL</b>	<b>Army JMR</b>	<b>USAF Air Mobility Command</b>
<b>Mission</b>	Airlift	Airlift	Multirole capable based upon attached module (airlift, ISR, EW, CAS)
<b>Price</b>	Affordable, attrition acceptable	Affordable	Inexpensive

Source: Mike Melnyk, "AMC Industry Day," slide 9; US Marine Corps, "Solicitation Number: M6785409R9015"; Air Mobility Command Specialized Contracting Branch, "Solicitation Number, RFI\_for\_Unmanned\_Cargo\_Aircraft"; US Marine Corps, *Universal Needs Statement (UNS) for the Cargo Unmanned Aircraft System (Cargo UAS)*; US Transportation Command Joint Distribution Process Analysis Center, "Request for Information: Future Deployment and Distribution Assessment"; and US Army Aviation Center of Excellence Concepts and Requirements Directorate, "Joint Multi-Role Aircraft Platform Industry Presentation."

## Appendix 4

### **Concept of Employment\***

#### **Purpose/Objective/Assumptions**

##### 1. Purpose/Objective/Assumptions

1.1. Purpose: This Concept of Employment (CONEMP) describes how the MQ-A Unmanned Intratheater Air-lifter will operate in support of United States Joint Forces across the full spectrum of military operations. The MQ-A will augment current and forecast aircraft utilized by the DOD with a focus on Time Sensitive (TS) and Mission Critical (MC) cargo movement.

1.1.1. Operators. All services will employ the aircraft in manners deemed appropriate by the Combatant and/or Functional Commanders. This may include a service centric or joint employment concept based upon available resources.

1.1.2. Time Sensitive /Mission Critical. "Time sensitive/mission critical mission requirements create a demand for delivery of equipment, supplies, and personnel that are generally non-routine in nature and must be delivered to the point of need / point of effect in an accelerated time period. These demands require the lift capacity to be supremely responsive to the supported commander's immediate operational or tactical priorities. TS/MC demands cannot routinely be accommodated via the planned resupply and movement processes where efficiency is the primary consideration."<sup>1</sup>

Dedicated airlift assets must be available and responsive to fulfill TS/MC requirements. As time-frame requirements for TS/MC cargo movement rarely allow for extensive delays between request and delivery, airlift assets must be available, re-

---

\*This document is printed verbatim.

sponsive, and flexible to fulfill the taskings as and when directed by the deployed commander.

1.1.3. Expeditionary Airlift Squadron. For the purposes of this CONEMP, units employing the MQ-A in the deployed environment will be referred to as Expeditionary Airlift Squadrons (EAS). These units will include, as a minimum, the aircrew (e.g. pilots and sensor operators), mission planners, maintenance personnel and all mission essential equipment necessary to support and operate the deployed assets. Due to the nature of remotely piloted aircraft operations and in the interest of maintaining a minimal forward footprint, the aircrew, mission planners and mission support personnel not requiring physical access to the aircraft need not be collocated with the deployed assets. Geographic separation from the deployed forces or the operation of multiple platforms simultaneously may require the modification of some [of] the procedures outlined in this CONEMP.

1.2. Objective: The objective of this CONEMP is to help fulfill TS/MC cargo lift and other multi-role requirements through the employment of the MQ-A in all operating environments. While the actual tactics and doctrine for the MQ-A's employment will vary with each service, the best practices should be captured in Service and joint doctrine, instructions, manuals and procedures.

1.3. Background: Current and arguably future conventional and counter insurgency operations will involve vast areas of operation and lengthy logistical support lines. These lines of communication are slow and difficult to secure, especially in the presence of insurgents. This limitation will drive an increased reliance upon airlift for the movement of critical personnel and supplies. Due to the extended mission ranges, high altitudes, increasing demands upon airlift, reduced accessibility to forward forces (i.e. in urban, wooded, and/or mountainous terrain), a greater reliance on just-in-time, TS/MC, and short notice movement missions, the

reliance upon existing organic rotary and fixed wing support is unrealistic.

A few select rotary wing assets, particularly the CH-47, are performing a majority of the TS/MC cargo and personnel movement missions due to the simple fact that they are [the] best resources available. Furthermore, current doctrine calls for rotary wing assets to always fly in formations of 2 or more aircraft regardless of the load being transported, even if only one of the aircraft has a small item or a single passenger. This current practice is both very expensive and inefficient. The long distances between staging locations and forward units have resulted in rotary wing assets accumulating flight hours well above anticipated mission profiles. This has resulted in increased maintenance and expenses, particularly with regards to rotor blades, engines and transmissions. The increased workload on these limited assets to move routine and TS/MC loads has also removed these aircraft from their primary function of supporting the ground combat unit movement needs.

Despite the significant effort being made to avoid ground threats by airlifting cargo and personnel over high risk areas, the airlift capacity is woefully short of requirements. Airdrop systems, although improving in accuracy, still require significant lead times and don't have the ability to reliably drop cargo on a small drop zone (e.g. on a ridgeline, parking log, or small clearing). OEF, like some previous military operations, have seen an extensive number of forces take up positions in relatively inaccessible and treacherous locations that have limited to no truck access. These limitations have driven the requirement for helicopter lift, even at the expense of ground force movement requirements. Unfortunately, however, helicopters are slow, of limited supply, and expensive to maintain, especially in harsh climates.

Regardless of the airlift advancements made to date, the limited number of airlift assets means that a majority of supplies must still be transported by ground convoy: a very risky and slow means of transport. Current and future logistical requirements dictate the introduction

of a more efficient, flexible and responsive airlift option. The MQ-A offers a flexible, responsive, inexpensive, and low risk option to fulfill TS/MC requirements thereby freeing larger manned assets to return to their primary mission of ground force movement support.

1.4. Assumptions: This CONEMP applies to the employment of forces in conventional, counter-insurgency, and military operations other than war. The concepts presented in this CONEMP are predicated upon the following assumptions:

1.4.1. Future operating environments will be similar to current operating environments with respect to FOB accessibility (i.e. a significant number of troop formations will be inaccessible to fixed wing resupply aircraft except with regards to airdrop).

1.4.2. Commanders will utilize MQ-A primarily for cargo movement and not for troop transport.

1.4.3. The USAF and USA will not field any additional aircraft models not currently employed in OIF and OEF (with the exception of the C-27) for the purpose of airlift.

1.4.4. Technologies discussed in this paper are not proprietary and thus can be combined into a joint platform (e.g. a Northrop Grumman aircraft can employ a Bell autoland system and a Boeing sense and avoid sensor package).

1.4.5. Current Service employment concepts (and subsequent supply requirements) will remain largely unchanged.

1.4.6. MQ-A assets will be apportioned to the joint force by the JFC and employed based upon the needs of the receiving functional commander.

1.4.7. It is possible for the supporting Expeditionary Airlift Squadron (EAS) and the supported unit to be of the same Service.

## **Organization**

### **2. Organization**

2.1. Overview: Due to the nature of the TS/MC requirements and force locations, the units employing the MQ-A will need to coordinate directly with the supported ground commanders. To help ensure these requirements are met:

2.1.1. The JFC will allocate forces to the functional and supported commanders based upon mission requirements. MQ-A support will be provided to supported units in the form of an EAS.

2.1.2. Each Service will provide liaison officers to the Combined Air Operations Center (CAOC) to coordinate tactical airlift requirements. The CAOC will maintain visibility on all tasked missions and will include regularly scheduled missions in the Air Tasking Order (ATO). Short or no-notice TS/MC missions and mission changes will be monitored via aircraft position sensors and crew reports.

2.1.3. Each EAS will include aircrew, planning and maintenance personnel. To facilitate coordination and integrated planning, the EAS will be collocated with the supported units to the maximum extent possible. The EAS will coordinate TS/MC missions with the supported ground commander directly.

2.1.4. Supported commanders will exercise TACON over allocated forces. While TACON will allow the supported commander to use and move forces as and when required to support mission requirements, it does not grant the supported commander waiver authority over DOD or Service regulatory guidance. OPCON will remain with the EAS Service component commander.

2.1.5. Short notice mission changes / requirements for supporting forces not allocated to the supported commander will be coordinated through the CAOC.

2.2 Command Relationships: The command structure for MQ-A equipped units will depend upon the Services



employing them. Two primary scenarios exist: 1) a single Service is the sole employer of the MQ-A and 2) the MQ-A is employed as a joint aircraft with each Service having them integrated into their respective logistical infrastructures.

2.2.1. MQ-A as single Service asset: The supporting Service commander will exercise OPCON and TACON over assigned MQ-A units and will support routine cargo movement requests IAW [in accordance with] established airlift request procedures. To better fulfill TS/MC mission requirements, the supported commanders will be assigned TACON over EAS (to include mission and maintenance support personnel) to ensure adequate short notice airlift is available when and where required by the ground forces. OPCON will remain with the owning Service commander.

2.2.2. MQ-A as joint asset: Each Service will employ the MQ-A in accordance with Service doctrine and procedures. Excess sorties will be made available to the JFC / common user pool for allocation to the other functional commanders through the CAOC. Aircraft sortie allocations will be based upon mission requirements. In these cases, the functional commander will exercise TACON over the allocated forces.

2.3. Force Generation: Each Service will maintain its own force rotation policies but will ensure that sufficient overlap occurs such that sufficient airlift support is maintained. This will include local orientation / familiarization training to ensure a smooth transition between outgoing and incoming forces. Each Service can position their respective Mission Control Element(s) (MCE) where they deem most effective. Each deployed EAS will include at least one fully qualified pilot. In the event that the MCE is not co-located with the supported forces, a Liaison Officer (LO) will be assigned to each deployed location to ensure optimal use of allocated resources.

2.4. Force Protection: Force protection for the EAS and supported unit will be provided by the supported unit / Service.

## **Intelligence**

### **3. Intelligence**

3.1. General: Timely and accurate intelligence information is essential to the successful execution of deployed operations. Intelligence provides enemy force capability and intent assessments to the commander, staff, and personnel executing the mission. A complete and accurate assessment of the operating environment as well as friendly and enemy forces is required at all stages of mission planning and execution. This is particularly critical in a tactical environment to ensure mission planners and aircrew can safely and effectively employ assigned assets with minimal risk to friendly forces and equipment. Tactical intelligence will be provided to aircrew and mission planners by theater intelligence personnel assigned to the supported commander prior to mission execution and to commanders upon request. Relevant intelligence information will be pushed to all applicable parties before, during and after mission execution as appropriate.

3.2. Responsibilities: Deployed intelligence assigned to the supported commander will support continuous flying operations. Intelligence research, analysis and dissemination will be provided in accordance with the supported command's applicable guidance (i.e. doctrine, procedures, instructions, etc.). Special emphasis will be given to threat identification and analysis. Intelligence personnel assigned to the EAS will provide supplemental information and will assume primary threat/risk assessment responsibilities in the event support is unavailable from the supported unit. Intelligence personnel will rapidly push any intelligence information that will impact current or future operations to the commander and affected units.

3.3. Pre-mission briefings: Intelligence personnel shall ensure all crews receive pre-mission briefings IAW theater directives:

3.3.1. Pre-mission briefings will follow theater checklists, with briefing items to include: review of general battle situation; geo-political developments with impact on operations; significant changes in order of battle disposition; mission objectives with appropriate imagery of the objective area; mission threat assessment to include immediate area threats, ingress route threats, objective area threats, egress route threats, and anticipated threats at recovery/divert/abort fields. Pre-mission briefings for manned flights will also include Personnel Recovery (PR) information.

3.3.2. The PR information provided to the pilot will include: a review of Combat Search and Rescue (CSAR) data on known survivors believed in the area of mission; review of Designated Areas for Recovery; theater authentication and recovery information; review of Evasion Plan of Action (EPA); and the provision of a PR kit with items as required by theater directives

3.3.3. Pre-mission briefings will conclude with debriefing and reporting instructions to include a review of the Essential Elements of Information (EEI) and Mission Report (MISREP) instructions

3.4. Post-mission debrief: Intelligence personnel shall ensure all missions are debriefed and all events are reported IAW theater directives:

3.4.1. Crew debriefings will follow applicable checklists focusing on potential threat events, to include: Missile Warning System (MWS) events, Surface to Air Fire (SAFIRE) events; Spectrum Interference Resolution (SIR) events, communication problems and lasing events; and sightings of interest.

3.4.2. Intelligence personnel will report all relevant events via MISREP within appropriate timeliness standards, IAW tasking authority requirements and theater directives

3.5. Threat Assessments: Supported unit threat assessment policies and directives will take precedence

over the supporting unit's threat assessment policies. Under TACON, the supported unit commander is granted risk acceptance authority. All available intelligence sources will be used to provide mission planners and aircrews with a comprehensive threat picture and unit intelligence personnel will manage requests for information (RFI) as necessary.

## **Operations**

### **4. Operations**

4.1. General: General flight operations will be largely dependent upon the EAS's Service guidance on the employment of the MQ-A. While the remotely piloted nature and autonomous capabilities of the MQ-A may lend itself to a higher risk acceptance level, differences in the guidance governing the employment of remotely piloted air assets will need to be resolved between the supported and supporting commanders prior to asset employment.

4.1.1. Risk Acceptance: The supported commander will conduct an operational risk assessment prior to employing the MQ-A. This assessment will consider, as a minimum, hazards presented by environmental conditions, enemy forces, cargo type and quantity, mission type, level of autonomy and operating area (e.g. urban, rural, mountainous, etc.). Operations in medium or high risk conditions will require a formal risk acceptance at a level appropriate to the risk being accepted. Risk assessment criteria, procedures and risk approval authorities will be agreed upon by the supporting and supported commanders prior to aircraft operation.

4.1.2. Waiver Authority: Each Service will maintain appropriate waiver approval authority over assigned forces in accordance with established guidance unless delegated to the supported commander.

4.1.3. Multi-Mission: The MQ-A is a common use platform with a modular design to facilitate a wide range of mission sets. To change missions, mission modules can be interchanged and attached to wing and fuselage hardpoints. To assist with changing, loading, and unloading the primary fuselage module, the MQ-A is equipped with an internal hoist system which is operated from an externally accessible control panel. While the module is in the up configuration, electrically powered latches engage ensuring the module remains attached to the aircraft during

flight. An electronic umbilical cord connecting the mission module to the MQ-A provides two-way communication between the module and the MQ-A's communications and flight control systems.

4.2. Tasking: Mission tasking is a multi-phased process that includes establishing mission requirements (traditionally presented in the form of an Air Mission Request (AMR)), a planning task and an execution task. To facilitate this process and ensure proper asset usage, Liaison Officers (LNO) will be integrated at the Higher Headquarters and supported/supporting unit levels. As the number of AMRs frequently exceeds available resources, supported unit commanders will validate and prioritize all airlift requirements/requests. Validated AMRs will be forwarded to the Plans cell.

LNOs at the Higher Headquarters and Air Mobility Division (AMD) will remain engaged during the entire tasking/planning process. In case of unfulfilled AMR requirements, the AMD LNO will forward a validated / prioritized list to the AMD for possible support. Supported unit LNOs to the AMD should monitor airlift requests to see if unused/excess supported unit missions may be suitable for AMD missions.

4.3. Planning: All EASs and supported units will provide representation to the joint planning and execution cells. The Plans and Execution Cells will be collocated and will coordinate asset usage to fulfill validated AMRs. Whenever practical, the EAS will consolidate validated AMRs to maximize effectiveness and efficiency. Opportune cargo movement requests can be approved by the EAS commander both prior to and during mission execution provided they will not interfere with scheduled flights. The EAS will notify the supported unit to coordinate mission changes.

4.3.1. Plans Cell: The Plans Cell will: plan/build missions based upon validated AMRs and established Service and Mission Design Series (MDS) guidance, build flight itineraries, determine ACL and loads, receive mission requirements, enter data into Global Decision Support System (GDSS), deter-

mine routes / tactics, determine fuel stops, coordinate with maintenance for tail availability and usage, and ensure all planned flights are on the ATO. The supported unit commander will be notified of any capability shortfalls as soon as possible. The supported unit commander will approve all mission plans prior to execution.

4.3.1.1. Cell composition: Each shift shall include, as a minimum: 1 x Pilot/Navigator/Combat Systems Operator; 1 x Loadmaster; 1 x Logistics Readiness Officer (LRO) requirements or 1 x Porter (2T2) requirements.

4.4. Execution: A mission is considered in execution once the crew has been alerted. All requests to change the mission once it is in execution must be forwarded to the supported unit commander for approval prior to altering the mission. Approved mission change requests will flow from the supported unit commander or his delegated representative, to the EAS or crew, as appropriate, via applicable aviation command and control procedures. Mission changes due to operational requirements will be forwarded up to the supported unit commander via the same command and control process.

The Execution authority for all missions is the supported unit commander normally exercised through the EAS commander. The Director of Mobility Forces (DIR-MOBFOR) will maintain 24/7 oversight on behalf of the CFACC [combined force air component commander] to include monitoring asset utilization and processing waivers for TS/MC missions.

4.4.1. Execution Cell: The Execution Cell will: alerts crews, execute missions, pass applicable info to the crew (i.e. MCE or MQ-A pilot), monitor mission progress, update GDSS, relay pertinent information to applicable parties within the CAOC, perform re-planning when necessary, and coordinate ATO changes.

4.4.1.1. Cell composition: Each shift shall include, as a minimum: 1 x Pilot/Navigator/Com-

bat Systems Operator and 1 x Command and Control Specialist (1C3) or equivalent.

4.5. TS/MC missions: The standard mission approval, planning, and execution process typically isn't responsive enough to fulfill TS/MC mission requirements. In these cases, the supported unit commander and planning/execution staffs will perform all airspace coordination and ensure the CAOC is aware of any new flights and changes to the ATO. This is essential for any mission that will be flown above the coordination altitude, outside designated supported unit controlled airspace, or in airspace that requires deconfliction to avoid fratricide.

4.6. Mission Monitoring. Mission monitoring will take place on multiple levels: CAOC, AMD, Execution Cell, EAS/Supported Unit, MCE, en route stop locations, and other applicable agencies. As such, mission tracking through established logistic tracking systems such as command and control systems, GDSS and the Joint Air Logistics Information System-Next Generation (JALIS-NG) is essential for proper mission visibility and planning.

Station command posts, the Execution Cell, and en route logistical offices will update all applicable tracking systems with pertinent information such as arrival time, departure time, advisory messages, cargo information, and maintenance status when new information becomes available.

4.6.1. Reports. All Operations/Mission/Situation Reports will be IAW established guidance.

4.6.2. Aircrew Responsibilities. The EAS command and control is the focal point for all mission support activities. The Aircraft Commander (either on the aircraft or in the GCS) must inform command and control of any factor that may affect mission accomplishment. When transiting a stop without a command and control agency, the Aircraft Commander is responsible for ensuring necessary mission information is placed into the command and control system by the most expeditious means available.



4.7. Operating Procedures: In the absence of Service specific technical manuals, doctrine and instructions for the employment of the MQ-A, this section recommends some standard operating procedures for consideration. Operations outside Service and/or joint operating instructions will be approved by the appropriate waiver approval authority.

4.7.1. Autonomous/Semi-Autonomous Operations: An RPA is considered autonomous when it has ability and is entrusted to make substantial real-time decisions without human involvement or supervision. A system's autonomy is independent of its ability to transmit information to another station for monitoring. Autonomous operations can rely upon pre-programmed waypoints or real-time internal logic determined routing. An RPA is considered semi-autonomous when it can operate partially or entirely autonomously but has a ground operator integrated into the control loop. In this case, a ground controller can offer revised direction to the RPA at any point during operation (e.g. ordnance release authorization, alter route of flight, etc.).

4.7.1.1. Semi-Autonomous Operations: Semi-autonomous operation is the preferred mode of operation. While the aircraft will take off and land autonomously, once the departure command is transmitted to the aircraft, aircrew should monitor the aircraft and mission progress so timely corrective inputs or mission / route changes can be provided when and where required. The MCE must be prepared to modify the aircraft's mission and/or flight path based upon changing mission requirements and encountered hazards.

4.7.1.2. Autonomous Operations: While it is preferable that a MCE monitor aircraft operation during all phases of flight, the MQ-A was designed to operate autonomously. Autonomous operations by their very nature are inflexible. Pre-programmed routes and missions are flown

with no MCE inputs once the aircraft departs. This may be done for a number of reasons: 1) a MCE is unavailable to monitor the mission / aircraft performance; 2) mission planners do not want the mission changed by external sources once the mission is initiated; or 3) the mission is considered routine and does not warrant mission monitoring by a MCE.

Situations where autonomous operation will be permitted will be prior coordinated between the supported and supporting commanders. The CAOC will be advised of all autonomous flights. Prior to operating the MQ-A autonomously, special consideration will be given to en route hazards (e.g. weather, enemy activity, etc.), landing zone hazards (e.g. terrain, obstacles, etc.), operating altitudes, route of flight, airspace, and air traffic control coordination requirements. The route of flight and/or operating altitude may need to be adjusted to account for en route hazards and flight restrictions.

4.7.2. Air Tasking Order / Airspace Control Order: All flights will be conducted in accordance with procedures and restrictions outlined in the ATO and ACO. All regularly scheduled flights will be included in the Air Tasking Order (ATO) and the Airspace Control Order (ACO) to minimize conflicts and friendly fire incidents. A sufficient number of transponder codes will be reserved for short notice taskings not included in the ATO and ACO. The CAOC will be notified of all flights that were not specifically scheduled in the ATO and ACO.

4.7.3. Flight Plan: The MQ-A will operate in both civil and military airspace while executing routine and contingency flights. In all cases flight planning and execution will be conducted in accordance with applicable airspace requirements.

4.7.3.1. Civil Airspace: Operation within civil airspace, even if transiting to or from a contingency area, will be in accordance with applicable

national and flight information region requirements. This may require specific routes, specific procedures, and/or the utilization of a pilot module.

4.7.3.2. Military Controlled Airspace: Flights in military controlled airspace shall be conducted in accordance with local operating procedures (e.g. military flight rules such as MARSA (military assumes responsibility for separation), ATO, ACO, etc.).

4.7.4. Weather: Adverse weather can have a significant impact upon flight operations. While the MQ-A can operate in reduced visibility conditions with limited to no impact upon normal operations, severe weather can result in aircraft loss and must be avoided.

4.7.4.1. Briefing: Aircrew will receive a weather briefing prior to conducting flight operations in accordance with the supporting unit's Service guidance. Supported commanders considering autonomous flight operations shall receive a full weather briefing for the entire intended route of flight prior to approving autonomous flight operations.

4.7.4.2. Ceiling and Visibility: Aside from landing zone validation, MQ-A operations are not significantly impacted by visibility restricting conditions (e.g. cloud, fog, white-out, brown-out, darkness, etc.). Provided the MQ-A has been provided sufficiently accurate landing coordinates, the MQ-A can take off and land in 0'/0 SM conditions (i.e. clouds down to surface and no measurable visibility). Commanders will assess the risk to ground personnel and equipment before approving operation in these conditions.

4.7.4.3. Severe Weather: Severe weather, to include icing, thunderstorms, hail, and heavy precipitation shall be avoided in accordance with

Service guidance. Operations in severe weather conditions can result in loss of aircraft.

4.7.5. Lighting: The MQ-A is designed to take off and land autonomously using onboard position sensors. Visual sensors are used purely for the purpose of landing zone validation and ISR and are not required to perform the landing itself. As airfield lighting is not required for the MQ-A to takeoff or land, airfield lighting is not required. However, to help ensure the safety of ground personnel and to aid in landing zone validation, airfield lighting should be employed when operationally feasible.

4.7.6. Crash Fire Rescue: Operational requirements and limitations often require US forces to operate out of unprepared or hostile areas. These areas seldom have a fully functional crash fire rescue capability. While this is less than ideal, the supported commander can accept the risk of operating into/out of areas with limited or no crash fire rescue capabilities.

4.7.7. Departure/Arrival: The MQ-A is designed to take off and land autonomously in all environmental conditions.

4.7.7.1. Departure: When the offload and/or onload is complete, ground personnel will either enter the coordinates or identifier for the next destination into the onboard FMS or select one of two options: 1) return to base (point of origin) or 2) continue to next en route stop. The desired route of flight can be loaded manually into the aircraft's FMS or remotely from the GCS. If a route of flight is not inputted, the FMS will compute a route of flight based upon known airways, threats, terrain, and airspace restrictions. Once the takeoff command is received from ground personnel or the GCS, the aircraft will wait a designated period (20 seconds unless indicated otherwise) to give time for ground personnel to achieve a safe distance from the aircraft. It will then power up the in-wing ducted

fans, perform an autonomous vertical takeoff, climb to a safe altitude and transition to forward flight.

4.7.7.2. Arrival: The MQ-A is capable [of] landing at three types of landing zones: 1) predetermined geographic coordinates (such as a landing pad on an airport); 2) a ground personnel directed point; or 3) on a small, portable, short range marker beacon / transmitter (easily carried by ground personnel or fixed on a ship). When approaching the pre-designated landing point, the MQ-A will transition to a hover at 2,000 feet above ground level (AGL) at the designated coordinates. The fielded forces, using PDA linked to the aircraft, will then accept the landing point, adjust the landing point, direct the aircraft to land on the marker beacon, direct the aircraft to hold, send the aircraft to its next destination, or send it back to base.

If a landing point is not acknowledged by the ground personnel the landing decision will be deferred to the monitoring aircrew. In the event of a lost link or aircrew unavailability, the aircraft will perform a predetermined function: 1) hold to await further instruction; 2) proceed to the next waypoint; 3) land at the designated coordinates / marker; or 4) return to base. The selected course of action will depend upon preloaded algorithms and/or the anticipated security of the intended landing zone.

Once approved for landing, the MQ-A will perform an autonomous vertical descent to landing utilizing onboard GPS / INS systems and thrust vectoring (via ducted fan louvers) to maintain a position directly over the intended landing position throughout the descent. This will allow the aircraft to land in a confined area without the ground personnel designating an approach corridor. It will also minimize side loading strains on the landing gear during landing and reduce

the chances of a landing role. In the case of ship operations, a crew monitoring the aircraft's progress will assume control, fly it to the target ship, lock the aircraft onto the mobile marker transmitter and direct the aircraft to land. The MQ-A will then assume a position over the marker and perform a vertical landing onto the deck.

4.7.8. Duty Day / Crew Rest: The supporting unit will comply with its Service specific crew rest and duty day limitations. Waiver authority for Aircraft Commander requested duty day waivers up to 2 hours may be delegated to the supported unit's equivalent command level.

4.7.9. Flight Surgeon / Medical Issues: EAS personnel may use the supported unit's Service medical staff (i.e. AF EAS personnel assigned to an Army unit may use Army medical staff).

4.7.10. Minimum Equipment List: Each Service's minimum equipment list (MEL) will contain, as a minimum, a list of required items for contingency operations. This list will also identify items that can be waived by the supported commander if aircraft operation is required to support a TS/MC mission. The waiver authority for aircraft operation with less than the required minimum equipment required for the specified mission will be in accordance with supporting unit guidance.

4.7.11. Fuel Reserve: At takeoff, the aircraft must have sufficient fuel to fly to its destination, hold for 45 minutes and then land or proceed to an alternate where fuel is available.

4.7.12. Alternate: Alternate airfields must be secure locations with a ceiling of at least 2,000' (1,000' if a means exist to alter the landing zone verification hover altitude while the aircraft is en route) or precise landing coordinates. If the landing coordinate option is used, the area immediately surrounding the intended landing zone must be clear of obstacles. Whenever possible, unverified landings should

be conducted using mobile landing zone beacons/transmitters.

4.7.13. En Route Procedures: The MQ-A can operate at altitudes over 30,000 feet and at speeds comparable to most jet aircraft. While the aircraft is equipped with terrain, hazard, and aircraft-avoidance technologies, every effort must be taken to ensure the intended flight path complies with established civil and military flight procedures and restrictions as appropriate to the airspace the aircraft is operating in.

4.7.14. Ground Operations: During takeoff and landing, the ducted fans will generate significant downwash. Loose material in the landing zone can become a hazard to personnel and may result in FOD ingestion. To minimize the risk to personnel and aircraft, the intended landing zone should be cleared of loose material prior to aircraft operation. Once on the ground, the MQ-A's wheels auto lock and the ducted fan is depowered and completely covered by its thrust vectoring louvers. To minimize exposure to blowing debris and fan contact, personnel should remain clear of the fan ports until the fans are depowered, the louvers are fully closed and the aircraft has fully settled. While the main engine is running, personnel should also use caution to avoid the jet exhaust when transiting behind the aircraft.

Once the desired cargo and/or mission modules have been off loaded and/or on loaded, the aircraft's next destination will be loaded into the FMS. Using the onboard FMS, or remotely via a controlling GCS, upload the destination (geographic coordinates or a location identifier code), a desired altitude (optional) and a route of flight (optional). Once the route has been loaded and verified, depress the takeoff button and egress the immediate area. The aircraft will wait 20 seconds (or less if desired) before powering up to ensure sufficient time for ground personnel to reach a safe distance. If a route of flight or altitude is not

selected, the FMS will select an optimum route and altitude based upon known threats, airways, restrictions and ICAO flight rules.

The weight of the pod attached to the center hoist system is calculated automatically by the MQ-A's hoist system. If this weight is determined to be inaccurate or additional pods or munitions are attached to the aircraft, the total weight of all external loads will be entered into the FMS manually prior to departure.

4.8. Environments: MOOTW [military operations other than war] and contingency operations require 24/7 support in all weather conditions. The MQ-A is designed to operate autonomously or semi-autonomously in all environments with minimal risk to personnel and equipment. While operating in a remotely piloted mode, the autonomous landing system is immune to environmental conditions that would otherwise contribute to human factor related mishaps (particularly spatial disorientation or visual illusion related mishaps). On board positional sensors also help mitigate the risk of collision with obstacles.

4.8.1. CBRNE: Unlike manned platforms, remotely piloted aircraft can operate in CBRNE environments with relative impunity for extended durations with little to no degradation in performance. This makes remotely piloted platforms an ideal choice for operation in these harsh conditions.

When conditions are deemed too hazardous for manned aircraft to operate, or if decontamination is a considerable concern, the MQ-A will be equipped with the appropriate mission module and operated in an autonomous or semi-autonomous mode. Upon completion of the mission, the aircraft will be refueled and sent back into the hazardous area or decontaminated for later use.

4.8.2. Hostile: Resupplying friendly forces engaged in close contact with enemy forces is a high risk mission for manned aircraft. While some of these missions may require manned aircraft due to



rapidly changing conditions or passenger ingress/egress requirements, the MQ-A provides a lower risk option for these hazardous conditions. The landing zone verification process allows the friendly troops to accept, delay, or deny receipt of the inbound cargo. The aircraft's small footprint will enable it to land in areas otherwise inaccessible to larger resupply helicopters such as the H-60 or even the H-1. This presents the ground forces with flexibility and greater force protection options without risking the lives of personnel on manned aircraft.

4.8.3. Threat Avoidance: The modern battlefield presents friendly aircraft with a wide assortment of threats ranging from small arms and AAA to SAMs and even other aircraft. The best chance for survival in this environment is to avoid the threat entirely (a necessity without countermeasures).

4.8.3.1. Hostile Fire: By flying outside the effective operating envelope of these threats, an aircraft can significantly reduce or even eliminate the chances of being hit by a given weapon. The MQ-A's range and wide operating envelope will enable the aircraft to fly around, over, or under the effective range of many threats. By using terrain following / avoidance technologies to fly at near treetop levels or through mountainous terrain at very high speeds, the MQ-A can minimize ground troop response times, get under enemy radar and even remain below the effective altitude of some ground threats. It can also cruise at altitudes over 30,000 feet to help reduce the risk of small arms, AAA, and SAM threats. Being able to hover at altitudes over 12,000 feet also enables it to hover at an altitude outside the effective range of small arms and some surface to air missiles while acquiring a landing zone or performing an ISR role.

The MQ-A's vertical takeoff and landing profile also allows it to avoid overflying hostile forces while flying a vulnerable, low and predictable

approach or departure path at slow speeds. The MQ-A's low profile and ability to land in small clearings (such as between buildings or between CONEXs [container express]) allows ground forces to be resupplied in relatively secure locations thereby minimizing the risk of ground fire while onloading or offloading. The additional use of a DIRCM [directional infrared countermeasures] equipped pod or other suppression/countermeasure systems can also help reduce the risk of hostile fire.

4.8.3.2. Other Aircraft: As airspace becomes increasing congested and the number of remotely piloted aircraft increases, the threat to and from other aircraft due to mid-air collisions will also [increase]. By using sense and avoid technologies linked into the flight control system, the MQ-A is able to identify and avoid other aircraft, even when they aren't equipped with or operating a transponder.

4.8.4. Low Visibility: Reduced visual conditions are a significant contributor to helicopter mishaps. Most prevalent of these are white-out and brown-out conditions which can lead to spatial disorientation or visual illusions in areas of loose snow or dirt. Likewise, the MQ-A can operate in conditions of low horizontal visibility such as in a dust, sand, or snow storms, conditions that would restrict or prohibit manned aircraft flight. Equipped with position sensors and an autonomous landing system that requires no visual cues, the MQ-A is able to operate normally in visually restricted conditions without performing a forward movement landing. While low ceilings and dense ground fog may restrict or inhibit the MQ-A's ability to take landing zone validation imagery, accurate landing zone coordinates or the use of a landing zone marker beacon/transmitter can negate this requirement. The aircraft's true vertical takeoff and landing profile further allows it to operate in areas deemed too hazardous for manned flight such as landing in a city street during a dust

storm. Due to the aircraft's ability to operate normally in low visibility conditions, the MQ-A will be the primary resupply option in visually restricted conditions (e.g. fog, low ceiling, loose or blowing sand/snow, etc.).

4.8.5. Mountainous: Mountainous terrain adds a significant challenge to flight operations. Rapidly rising terrain and narrow canyons can make maneuvering difficult. High pressure altitudes can also significantly reduce the performance of most rotor-wing aircraft. A high precision navigation system ensures the aircraft remains on course in all weather conditions. The MQ-A's terrain database coupled with its Automatic-Ground Collision Avoidance System further prevents ground collision should the aircraft get off course or be given a route of flight that would otherwise result in terrain impact.

The aircraft's ducted fans enable it to hover at altitudes up to 12,000 feet making most mountain landings a low risk event. Using the onboard terrain database, the flight management system automatically determines the landing zone elevation and adjusts the descent profile and hover altitudes to accommodate resupplying forces on mountains, hills or ridgelines. Coupled with the all weather precision course guidance, high altitude hover capability, terrain mapping, and terrain avoidance capabilities, the MQ-A can provide resupply service in mountainous terrain even with restricted or no visibility.

4.8.6. Urban: Urban environments present a unique challenge due to the immediate proximity of manmade structures, vegetation, power/telephone lines, and other obstacles. The confined nature of this environment makes helicopter resupply difficult and potentially very hazardous. The MQ-A's small footprint and vertical approach and departure paths make ingress and egress from these confined areas a far lower risk activity. The landing zone validation imagery and adjustment capability will allow ground troops to approve or modify the desired

landing zone based upon changing requirements or unforeseen conditions (such as unexpected power lines or vehicles in the pre-programmed landing zone). The small landing zone beacon/transmitter further enhances landing options, especially if sufficiently accurate coordinates cannot be obtained or the intended landing zone is visually obscured from above by sand, snow, fog, etc.

4.9. Contingency Operations: The MQ-A is a multi-role, all weather, autonomous or semi-autonomous remotely piloted platform capable of high speed, high altitude and low-level terrain following flight with little preflight preparation time required. With a small footprint, high altitude hover and VTOL capabilities, an ability to operate into and out of virtually all locations to include little degradation in performance in CBRNE, hostile fire, or low visibility conditions, the MQ-A is the primary platform of choice for small cargo loads, short notice taskings and operations in hostile environments. Changing the mission modules will allow the MQ-A to perform a wide variety of missions when and where required.

4.9.1. Positioning/Depositioning: Capable of self sustained flight of over 1,300 nm using internal fuel tanks (and no mission modules) or 2,100 nm using an extended range fuel tank module, the MQ-A can either fly itself to a forward staging location or it can be broken down and transported via C-17, C-5, truck and/or sea lift in 20 foot shipping containers. The mission modules will be transported via airlift, truck, or sea lift (based upon mission requirements). Aircraft service equipment and personnel will be transported via strategic and tactical lift based upon mission requirements and transport availability.

4.9.2. Cargo Lift: Using a cargo module attached to the fuselage, the MQ-A will transport small cargo loads (up to 3,000 pounds) to forward locations up to 500 nm away with enough fuel to return to base. Cargo transported in the cargo modules or the back of the pilot / passenger module will be secured to the maximum extent possible. Cargo can be loaded ei-

ther directly into a cargo module already attached to the aircraft or into a standalone module for later upload/attachment. While the cargo modules are climate controlled, they are not pressurized. As such, consideration should be given to identifying or restricting the transit altitude.

*Sample Scenario: Soldiers engaged in heavy fighting 230 miles away require immediate resupply of ammunition and medical supplies until they can be either extracted or reinforced. Low visibility due to a sand storm has made resupply or extraction by manned rotor-wing assets already in theater impossible and close air support too dangerous.*

*After receiving the call for supplies, the Movement Control Team (MCT) gathers the requested supplies and loads the cargo module already attached to the MQ-A being preflighted for the mission. Meanwhile, the landing zone coordinates provided by the fielded forces are loaded into the mission crew element's flight planning software. A route of flight is then determined and transmitted to the MQ-A's FMS. Once the cargo is secured in the cargo module, the load team depresses the takeoff button next to the FMS and the launch sequence commences.*

*20 seconds later, the ducted fan lowers open, exhaust air is ported from the engine to the ducted fans and the aircraft performs a vertical takeoff. After reaching 500 feet, the MQ-A transitions to forward flight, cruises to the designated landing zone coordinates at 250 kts and assumes a hover 2,000 feet above target area. While the sand storm has prevented visual confirmation of the landing zone, the troops direct the aircraft to land on the mobile landing zone transmitter already placed in the center of the intended landing zone. The MQ-A locks onto the short range transmitter, commences its vertical descent, and lands in the middle of the landing zone.*

*Once on the ground, the ducted fans are depowered and the lowers close. Meanwhile, the ground troops quickly remove the supplies from the cargo module,*

*secure the doors, and depress the return to base button. 20 seconds later the MQ-A jumps off the ground and returns to base.*

4.9.3. Airdrop: Not all locations can support a VTOL aircraft on the ground. This may be due to excessive threat or a lack of a sufficient landing zone. In these cases, an airdrop module can be used to transport supplies to a target area and then drop them with or without a parachute. The preferred method of airdrop will be from a hover position but airdrop from forward flight can be accomplished if required for mission accomplishment or aircraft safety. All airdrop missions will be flown semi-autonomously with the RPA pilot visually confirming the drop zone prior to package release.

4.9.3.1. Small Package Airdrop: The small package airdrop module utilizes trap doors on the bottom of a standard sized cargo module to selectively release small packages. Each bundle can be equipped with or without a parachute depending upon mission and drop requirements.

4.9.3.2. Module Airdrop: The modular airdrop option involves dropping the entire module with up to 3,000 lb. of supplies with or without a parachute (depending upon mission and drop requirements). This is primarily used for loads that are too large to be dropped via the small package airdrop module. During contingency operations, airdrop modules should be considered expendable. During non-contingency operations (e.g. training), airdrop modules that were dropped with a parachute should be recovered.

4.9.4. Passenger Lift: While not designed for passenger lift, this is a viable option if other troop transport options are not available. Three primary scenarios exist where passenger transport may occur. In all cases it is essential to keep in mind that although the modules are heated the modules are not pressurized. Thus the aircraft's en route flight altitude should be restricted to not higher than 10,000

feet and at no time higher than 12,000 feet. While passengers are not on board the aircraft, the web seat(s) can be secured against the module wall and cargo can be loaded in its place. All takeoffs and landings will be conducted autonomously.

4.9.4.1. Option 1 (Pilot/Passenger Module – Piloted): Using a pilot module configured for a pilot and three passengers, a MQ-A pilot can semi-autonomously or manually fly the aircraft to the destination, land, onload or offload the passenger(s), and then either continue a mission or return to base. Piloted missions do not require active mission monitoring by a MCE unless mission requirements or EAS guidance dictate otherwise.

4.9.4.2. Option 2 (No-Notice Emergency Egress: Cargo Module – No Pilot): The second most likely scenario for passenger movement is a no-notice emergency egress or transport. In this case, a MQ-A, configured for cargo transport, is required to extract a small team or a seriously injured patient from a hostile environment. Personnel wishing to utilize this option should coordinate their intentions with the MCE in the GCS via the aircraft's direct communication link.

In this case, the cargo module can be emptied (if required) and the passenger(s) can be placed inside the module. In this scenario, the ground personnel must ensure an altitude (and destination) is programmed into the FMS that will be conducive to passenger transport. This can be done either manually through the FMS or remotely by the GCS. Furthermore, if the module is not configured with fold down seating, the only means of securing the passenger(s) may be the cargo tie-downs. In this case, a high potential for personal injury exists. Occupants should make every effort to minimize movement inside the module once the aircraft commences flight.

4.9.4.3. Option 3 (Pilot / Passenger Module–No Pilot): Until the MQ-A's reliability and safety have been proven, and personnel are willing to be transported by a remotely piloted aircraft, this scenario is highly unlikely. However, if this option is deemed desirable, a pilot module can be loaded with the module's flight control authority deactivated (to prevent inadvertent passenger activation). To facilitate emergency communication between the passengers and the MCE, a communication link (either radio or SATCOM) will be kept active. In this configuration, all passenger carrying flights will be operated semi-autonomously for the duration of the flight.

*Sample Scenario: There is a short notice tasking to move two passengers to a FOB 300 nm away but no helicopters will be able to depart for another 2 hours. After coordinating with the EAS commander, the supported unit directs the MCE pilot to fly the two individuals to the FOB. While the pilot calculates and loads the route of flight into the FMS, the MCT lowers the cargo module from the fuselage using the internal wench system, detaches it, pushes the MQ-A over the waiting pilot / passenger module, connects the umbilical cord, hoists it into position and engages the electrically powered locks.*

*The pilot then performs a preflight, ensuring proper module-aircraft interface and calls for the passengers. The two passengers are escorted to the aircraft where they receive a safety briefing by the pilot and are secured in their seats. A few minutes later the aircraft powers up, performs an autonomous takeoff, and starts the flight to the FOB.*

*Less than an hour later, the pilot directs the aircraft to land and the MQ-A performs the 2,000' vertical descent to landing. Once on the ground, the in-wing ducted fans are depowered and sealed behind the louvers. The passengers disembark and the pilot takes control of unsched-*



*uled cargo that needs to go to another FOB before the aircraft returns to base. After receiving a quick approval for the mission change from the operations center, the pilot modifies the flight plan and departs. After a quick stop at the second FOB to drop off the cargo and onload fuel, the pilot returns to base with some mail and other small items of opportune cargo.*

4.9.5. ISR: Using one of three ISR modules, standard, armed and side scan, the MQ-A can perform both armed and unarmed ISR missions. However, the MQ-A should not be considered the primary ISR platform. The MQ-A trades loiter time for speed, mission flexibility, a wide operating envelope, safety, and an ability to hover thousands of feet over a target area. These traits make the MQ-A an excellent choice to respond to short notice or urgent ISR requirements at extended distances. The MQ-A can get to the target area faster than the Predator, Reaper, and Warrior, can perform the ISR mission, hand it off to another aircraft (such as a Reaper) when it arrives and then either perform another mission or return to base.

The standard and armed ISR modules utilize the same sensor package as can be found on current ISR RPAs. Due to the extra lift capacity, the remaining space in the module is used for either a fuel bladder for enhanced persistence (i.e. standard ISR module) or a multiple ejector ordinance rack (i.e. armed ISR module). The net-centric side scan module is equipped with a side scan radar that transmits the radar hits to other compatible aircraft (such as the J-STARS, RC-135, F-35, or F-22) operating within transmission range.

All ISR missions (armed and unarmed) shall be flown semi-autonomously with all takeoffs and landings performed autonomously. Target acquisition and weapons engagement shall be conducted by the MCE.

*Sample Scenario: A special forces team has potentially identified a high priority target in a mountain village but the RQ-1 currently monitoring the target only has another hour's worth of loiter time before it must return to base for refueling. As the target is only 180 miles away from the FOB, the CAOC has requested that a MQ-A launch in an armed ISR configuration to continue the surveillance and possibly engage.*

*A MQ-A is quickly configured with an armed ISR module and sent on its way. As the aircraft approaches the surveillance area, the MQ-A MCE clears the RQ-1 back to base and assumes the surveillance. Once positive verification is received that the individual is in fact the suspected high priority target, the MCE is directed to engage. The pilot locks onto the target and fires a Hellfire missile. After confirming that the target has been neutralized, the MQ-A assumes an ISR CAP in that area until a MQ-9 is able to replace it a few hours later.*

4.9.6. Bomber: Configured with any of an assortment of bomb modules, the MQ-A can function as a remotely piloted bomber platform. The aircraft's high airspeed and operating altitude allow it to quickly reach any target area within a 500 nm radius thereby reducing response time and enhancing ground support capabilities. Limited by weight, the multiple ejector bomb rack configurations can vary based upon mission requirements and desired endurance (increased ordinance weight decreases endurance). Once the bomb module is loaded several mission scenarios exist:

4.9.6.1. Autonomous vs. Pre-Programmed Fixed Targets: Similar to a cruise missile, the MQ-A is pre-programmed to fly a designated route against a designated fixed target(s) (e.g. a building, bridge, runway, power station, etc.). Upon reaching the designated drop point, the MQ-A will drop a predetermined type and quantity of ordinance before proceeding to the next target or returning to base. Functioning in an autono-

mous mode, the aircraft becomes a launch and forget platform until such time as it arrives at its designated landing point. The aircraft's progress can be monitored but no further inputs are required from the MCE to execute the mission.

4.9.6.2. Semi-Autonomous vs. Pre-Programmed Fixed Targets: Operating in the same manner as the Autonomous vs. Pre-Programmed Fixed Target mission, the Semi-Autonomous vs. Pre-Programmed Fixed Target mission has one significant difference, MCE input is authorized, or possibly even required prior ordinance release. At any point during the mission profile, the MCE can alter the aircraft's route, destination, or ordinance release details. This mission profile is preferred if the target(s) requires visual identification prior to ordinance release or if there is a high likelihood of a mission change before the aircraft returns to base.

4.9.6.3. Semi-Autonomous vs. Pre-Programmed Dynamic Targets: Unlike the Autonomous and Semi-Autonomous vs. Pre-Programmed Fixed Target missions, the Semi-Autonomous vs. Pre-Programmed Dynamic Target mission involves targeting opportune targets or late notice targets. In this case, the MQ-A will most likely be directed to hold in a designated holding area until such time as a potential target is identified. At which time the MCE transmits the target coordinates to the orbiting MQ-A. The aircraft then flies to the target, releases the desired ordinance, and either returns to a designated holding point or returns to base.

4.9.6.4. Semi-Autonomous Close Air Support: In a similar manner to the Semi-Autonomous vs. Pre-Programmed Dynamic Targets mission, the MQ-A is launched and sent to a designated holding area. When friendly forces require close air support, the MQ-A will respond to the target area and take a general area photo from an alti-

tude outside the expected surface to air threat range. The photo is transmitted to the engaged ground troops and displayed on a PDA. The ground troops can then zoom in, tap on the desired target, and transmit the new target location to the orbiting MQ-A. The MQ-A will then drop the desired ordinance on the designated target(s). Utilizing glide bombs can help improve standoff distance while the use of laser guided and/or GPS guided bombs can improve accuracy. In this scenario, the role of the MCE is minimized while the bulk of the route and target planning is conducted by the fielded ground forces. In this case, although the ground forces will perform a majority of the target identification, the MCE will monitor aircraft performance and targeting to minimize chances of fratricide and help reduce the risk of a mishap.

*Sample Scenario: With no cargo or TS/MC mission requirements, two MQ-As have been released to the common use pool for tasking. An hour later the CAOC tasks one of the MQ-As to bomb two targets to help prepare the battlefield for a pending ground operation. As the targets are two undefended bridges 450 miles away, the EAS opts to execute an autonomous mission saving the sole legal crew for other operations.*

*With the ordinance selected, the MCT replaces the cargo module with a bomb module and uploads the required precision munitions while the flight plan is uploaded to the FMS. Once the bomb release points are calculated and the munitions are programmed, the launch command is given. 20 seconds later the MQ-A powers up and departs on its pre-programmed route. At the pre-designated point, the MQ-A releases the first set of GBU-49s from 30,000 feet and then proceeds to the second target. After hitting the second target the MQ-A returns to base having disabled both bridges.*

*Having flown the entire mission autonomously with only position monitoring along the way, the MQ-A arrives over the home station just under 3 hours after departure. After coming to a hover 2,000 feet over the landing pad, the launch and recovery team approves the landing via the PDA. The MQ-A performs the 2,000 vertical descent and lands on the landing pad for reconfiguration and refueling.*

4.10. Military Operations Other Than War: Many of the same missions that would be performed during contingency operations will also be conducted during MOOTW. The most likely of these missions involve cargo movement and surveillance. The ability to change missions by simply changing the mission module provides the force with a significant level of flexibility and responsiveness to changing mission requirements.

4.10.1. Supply: In all types of MOOTW, the MQ-A can be used to transport cargo and supplies several hundred miles to the point of need rapidly and inexpensively. Supply missions during MOOTW will mirror the Cargo Lift mission conducted during contingency operations. The aircraft's wide operating envelope and ability to operate into and out of unprepared locations makes the MQ-A an ideal choice for on demand movement of TS/MC supplies to all types of locations. The low exhaust temperatures and the MQ-A's small footprint enable it to land in areas inaccessible to many helicopters. Its ability to operate in controlled airspace with or without a pilot on board also allows it to be used during peacetime in the US or anywhere the aircraft is required without establishing specialized airspace or making special arrangements with air traffic control services.

4.10.2. Humanitarian Relief: Humanitarian relief missions, such as those conducted in response to environmental disasters (e.g. earthquake, tsunami, forest fire, etc.) or significant manmade events (e.g. genocide, CBRNE, civil war, etc.) often involve damage/threat assessment and the mass lift of consum-

ables and medical supplies. In these cases, roads are often impassable (e.g. washed out, covered in debris, etc.) or too dangerous (e.g. threat of ambush, unstable roadway, etc.) to move mass quantities of supplies over long distances.

The MQ-A provides a means to transport large amounts of supplies, in small quantities, to a significant number of dispersed locations without deploying a significant number of manned aircraft and supporting ground personnel. Furthermore, movement along insecure, damaged, congested, or unprepared roads is often slow or even impossible resulting in extensive delays between their departure from a supply hub and their arrival at the point of need. The MQ-A will cut this time exponentially, especially over longer distances (e.g. 40 minutes to fly 200 nm vs. over 4 hours to drive it – assuming the roads are even passable). In the case of unstable and/or hostile environments, the MQ-A will transport supplies over the hazardous territory without risking convoys, manned aircraft, or their crews. Rescue workers will then receive the aircraft, unload the supplies and send the MQ-A back to the major distribution point for more. This distribution method will also help reduce the number of large supply hubs while simultaneously reducing the carbon footprint required to support them.

While performing these missions, the EAS commander will determine when the MQ-A will be operated in autonomous or semi-autonomous mode. Factors to be taken into consideration include, but are not limited to, atmospheric conditions, risk of hostile activities, condition of landing zones, level of training / competency of ground personnel expected to load, unload and launch the aircraft, number of ground control PDAs, and hazardous terrain (e.g. significant number of power lines, downed trees, etc.).

4.10.3. Surveillance: Equipped with the standard ISR module, the MQ-A can perform many peacetime surveillance missions. In addition to performing ISR

during a contingency operation, the MQ-A will conduct surveillance for the purpose of border patrol, coastal defense, counter drug operations, disaster and threat assessment, ground activity monitoring, and other overt and covert operations. Surveillance missions will be flown semi-autonomously.

4.10.4. Search and Rescue: Search and rescue missions typically require a significant number of resources to effectively search a large area on foot and from the air. This function is typically performed by civil air patrol and military aircraft visually scanning the target area in search of an aircraft or missing individual(s). Due to limitations of a visual search, the operation must be conducted in good weather during hours of daylight.

The MQ-A, utilizing the standard ISR module, can help find heat sources and other objects 24 hours a day. Once located, the MQ-A can hover over the site and an emergency survival kit can be dropped to the survivor(s) from one of the aircraft's hard points. The MQ-A can then either maintain a hover over the site or assume an observation orbit until manned rescue assets arrive to extract the personnel and/or equipment. If equipped with the CSAR module, the rescue basket can be lowered to extract the crewmember(s). The added operating hours, enhanced optical scan capabilities, ability to resupply, ability to extract crewmembers, and an ability to maintain a sustained observation position until rescue personnel arrive can all mean the difference between life and death.

4.11. Training: To ensure successful joint operations, all EAS personnel and ground personnel who may be serviced by the MQ-A must be proficient in the operating procedures of the other Services. EAS personnel must be further proficient in all mission sets. The required proficiency levels will be maintained through joint training and common doctrine, procedures and techniques. Maintaining common operating procedures will further help reduce the chances of negative transfer when operating in a joint environment.

4.11.1. Communication training: Aircrew and ground personnel shall receive training on phraseology and communication equipment used by all Services.

4.11.2. Participation in Joint exercises, Joint Airborne/Air Transportability Training (JA/ATT) and Air Training Exercises (ATX) will enhance communication and cooperation between air and ground elements. The JA/ATT program should emphasize and incorporate TS/MC events.

4.11.3. EAS planning cell, aircrew and LNOs associated with TS/MC missions should attend pre-deployment training with the supported unit(s).

4.11.4. Ground personnel who may operate around, service, load or unload the MQ-A shall [receive] specialized handling training. This training shall ensure personnel are familiar with how to operate with the aircraft in an operational environment. This training will include how to review, approve, and modify landing instructions via the ground control PDA, change missing modules, and how to review, modify, and input flight instructions via the on-board FMS. Refresher training will be accomplished as required prior to deployment.



## **Logistics/Sustainment**

### **5. Logistics / Sustainment:**

5.1. Cargo and Passenger Processing: The supported unit will provide a MCT and personnel to perform the arrival/departure airfield control group (A/DACG) operations to support cargo and passenger handling operations at the supporting EAS's main operating base. These MCTs will have personnel trained and certified for loading and unloading all MQ-A mission modules. To help expedite the loading and unloading process at locations not serviced by a MCT, supported commanders shall ensure all supported personnel are trained on basic aircraft operation (i.e. load, unload, launch).

5.1.1. Standard Cargo Movement. Standard cargo shall be required no earlier than 24 hours prior to scheduled departure. The MCT shall inspect and prepare all cargo. The supported unit shall establish a cargo priority system and inspect, prepare and document all cargo loads.

5.1.2. Short-Notice Cargo Movement. Many TS/MC cargo loads will be shipped in much less time based upon mission requirements and aircraft availability. The Aircraft Commander will attempt to contact the supported unit commander (or designee) for coordination and approval. If contact cannot be established, the Aircraft Commander will use his/her best judgment. Generally, last minute or opportune cargo should be accommodated if it won't adversely impact the mission.

#### **5.1.3. Passengers:**

5.1.3.1. Passenger show times will normally be 1 hour prior to departure, but not more than 2 hours prior to scheduled departure time. Passengers will wait in a passenger-holding area established by the supported commander until escorted to the aircraft.

5.1.3.2. If the aircraft will be flown remotely, the aircraft safety briefing will be provided to passengers by the supported unit's passenger processing personnel. If the MQ-A will be flown by a pilot in the pilot/passenger module, the passenger safety briefing will be provided by the aircraft commander.

5.1.4. Forward Operating Bases With MCT: Users will drop off intended cargo for transport with the MCT who will process and load the cargo. The MCT will certify all hazardous cargo prior to transport. Cargo and passenger information will be logged into applicable logistics tracking system(s) if available.

5.1.5. Forward Operating Bases/Austere Locations without MCT: Although most major forward operating bases will have personnel trained on how to load and unload cargo from the MQ-A, some air-land delivery and pickup locations will be made to austere locations with little or no formally trained cargo handling personnel. A placard will be posted on the side of the cargo modules with basic operating instructions including proper module door operation and how to launch the aircraft. An additional placard will also identify the maximum authorized cargo weight and refueling procedures.

If no automated logistics tracking system is available, the cargo manifest, if produced, shall be left with the cargo inside the cargo module and processed at the first capable location. If the FOB is unfamiliar with, or has no formal process for processing/manifesting passengers, a passenger manifest will be left with the local ground commander prior to departure. Every effort will be made to accommodate movement of opportune or last minute cargo and passengers provided it will not negatively impact the scheduled mission.

5.1.6. TS/MC Supported Ground Commander/User. The supported ground commander will adhere to the established movement timetable and ATO as much as possible. The EAS in conjunction with the

supported commander will determine timeline deviations as required to meet TS/MC mission objectives and requirements. The supported ground commander will also correct all discrepancies found by the A/DACG, MCT, ATOC [Air Terminal Operations Center], or mobility force.

5.1.7. A/DACG; MCT; ATOC (*If established at the airstrip/LZ/FOB*). The supported unit's movement control personnel shall:

5.1.7.1. Perform the joint inspection hazmat certification of aircraft mission loads and manifests.

5.1.7.2. Process and handle passengers in accordance with Service guidance.

5.1.7.3. Ensure passenger and cargo manifests are correct.

5.1.7.4. Enter cargo/passenger data into the selected in-transit visibility manifesting system.

5.1.7.5. Ensure the user corrects joint inspection hazmat certification discrepancies.

5.1.7.6. Maintain statistical data to account for the current status of all equipment, supplies, and personnel in aircraft loads.

5.1.7.7. Ensure the user adheres to the established movement timetables.

5.1.7.8. Provide loading team personnel and support equipment.

5.1.7.9. Ensure all personnel are briefed on flight line safety, to include driving procedures, smoking rules, hand signals, and any local special precautions, restrictions and procedures.

5.1.7.10. Retain a copy of corrected passenger and cargo manifests, hazmat certification records, and inspection records. A copy of all load documents will be provided to the aircrew. If the crew is not collocated with the aircraft, all pertinent data will be briefed to the MCE.

5.1.7.11. Provide fueling, defueling, and emergency maintenance capabilities for deploying unit equipment.

5.1.7.12. Establish and operate a passenger processing and holding area.

5.1.7.13. Escort passengers to the aircraft.

5.1.7.14. Brief passengers on aircraft safety if the MQ-A will be piloted remotely.

5.1.8. EAS Supporting TS/MC. For TS/MC operations at austere locations, the EAS will coordinate all mission requirements and confirm aircraft configuration with the supported ground commander/user. Mission changes will be coordinated through the supported unit commander.

5.2. Common User Utilization: When practical, excess capacity will be released to the AMD in support of the common user airlift pool. Load requirements will be submitted IAW GCC procedures and priorities. Common user movements will be monitored by the Air Mobility Division/Deployment and Distribution Operations Center (AMD/DDOC) and will not take precedence over TS/MC requirements.

5.3. Aircraft Maintenance:

5.3.1. Aircraft Maintenance. Normal aircraft maintenance will be conducted by the EAS and supported by the supported unit. Data/forms management will be conducted through the EAS's Service approved Maintenance Information Systems. During deployed operations, maintenance personnel will perform actions consistent with day to day flying activities. Extended heavy maintenance and scheduled inspections and above may be conducted at a designated heavy maintenance location. The home station check equivalent may be conducted in theater. The aircraft will deploy with a minimum logistics manning package, supply assets (mobility readiness spares packages (MRSP)) and support equipment to sustain 24/7 operations for an initial

30 day period. Additional equipment will follow via strategic movement in the most expedient manner possible arriving NLT 30 days from initial employment. The Logistics/Maintenance Unit will be equipped and manned accordingly.

5.3.2. Aircraft Generation. Aircraft generation is the cumulative effort required to launch and recover sorties. It includes activities that generate sorties and train personnel to generate sorties, and is predominantly accomplished in an on-equipment environment. EAS units will sustain capability to accomplish sortie generation for peacetime and wartime taskings. On-equipment maintenance is performed to prevent equipment/system failures, repair them when they occur, and improve airframe availability and reliability. Aircraft technicians ensure mission accomplishment by launching and recovering aircraft. During the launch and recovery of aircraft, deficiencies will be identified on aircraft and equipment and repair priorities will be aligned to most effectively meet mission requirements.<sup>2</sup>

5.3.3. Procedures. Personnel will perform maintenance IAW applicable technical orders and technical references. Aircraft waivers will be accomplished IAW the EAS Service directives.

5.3.4. Contract Support: Aircraft could be maintained at the organizational and depot level by a contractor via Contracted Logistical Support (CLS) / Interim Contractor Support (ICS). This includes actions and tasks involved in the servicing, repairing, testing, calibrating and inspecting to retain or restore aircraft and its related support equipment to a mission capable condition. Contractors will follow standard maintenance policy and procedures as outlined in the applicable contract or contractor deployment plan. The contractor will be responsible for spares, perform all maintenance, and repair at bed down locations and overseas contingency operations as required by supported commanders.

5.3.5. Weapon System Spares and Supply Support: Normally, intra-theater supply support will be provided using MRSP designed to support a specific number of aircraft. All reach back for mission capable (MICAP) and MRSP replenishment will come from the supporting Service's logistical support system (e.g. Air Force Global Logistics Support Center (AFGLSC)). The Standard Base Supply System (SBSS), or Service specific supply management system, will be used for retail accountability, issue and return of all spares, test equipment and support equipment. The inventory control point will maintain the capability to surge and self-support at en route, bare base, or wartime combat locations for 30 days without resupply through the use of MRSP.

5.4. Other Logistics. All other sustainment for the EAS will be provided by the supporting Service except for theater support normally provided to the other Services by doctrine, DOD Directive, JFC directives, or other intra-Service support agreements. Base operating support agencies will coordinate and assist in formalizing MOU [memoranda of understanding/MOAs [memoranda of agreement] as required.

## **Communication/Navigation**

### **6. Communication / Navigation:**

6.1. General. Airlift aircraft must be able to operate in all types of airspace: domestic, international, and contingency/military airspace. Unique airspace requirements will require the use of specific communication and navigation systems and/or capabilities. Failure to have all required communication and navigation systems may result in restrictions or denial of airspace entry.

6.1.1. Civil (Domestic and International): To legally operate in civil airspace, the MQ-A must maintain operational communication and navigation equipment that is in compliance with the established airspace entry and transit requirements outlined in applicable aviation regulations (e.g. FAR/ AIM, ICAO, GP/AP). This equipment must be interoperable and reliable, and must function within the Communication Navigation Surveillance / Air Traffic Management (CNS/ATM) structure [formerly known as Global Air Traffic Management (GATM)]. Due to the operating environment of the MQ-A, this includes equipment necessary to comply with Reduced Vertical Separation Minimum (RVSM), Minimum Navigation Performance Specifications (MNPS) and oceanic crossing requirements.

Some national airspace systems do not allow remotely piloted vehicles to transit the airspace. In these cases, special coordination may be required with the ARTCC controlling that airspace to permit a one-time transitory flight and/or specific routing. If an agreement cannot be met that will satisfy mission requirements, or if preferred for alternate reasons, the MQ-A can be piloted and flown directly from the pilot / passenger module. In so doing, the MQ-A becomes a manned aircraft and can be flown IAW established airspace requirements and procedures.

6.1.2. Contingency (Battlespace/Operational Environment): Due to its role in delivering supplies,

ISR services, transport, and close air support of forward forces in the tactical area of operations, aircraft must include secure communications, navigation, the latest Identification Friend or Foe (IFF) and other data equipment that enhances the battlespace awareness of the crew and the forces it supports. Any communication gaps between the MQ-A's operators and fielded forces will need to be addressed and resolved by the supporting and supported commanders prior to aircraft employment.

6.2. Radios: To ensure maximum operability, the MQ-A is equipped with UHF, VHF, HF, and SATCOM radios to facilitate communication with other aircraft (military and commercial), Command Post, Tower, Radar Approach Control (RAPCON), Air Traffic Control Centers (ATCC)/Air Route Traffic Control Centers (ARTCC), and fielded forces. Guard frequency monitoring and transmission capabilities must be available for emergency broadcasts. Communications regarding aircraft status, maintenance, in-flight emergencies, and cargo operations are normally coordinated through the Command Post, or in the absence of a Command Post, with the fielded forces directly.

6.3. Datalink: While the MQ-A is capable of fully autonomous operations, mission progress monitoring, communications, and semi-autonomous operations rely upon stable and secure datalink with the GCS. Loss of datalink with the GCS can have a significant impact upon mission success.

6.3.1. Bandwidth: Due to the extensive bandwidth requirements of net-centric and remotely operated vehicles, bandwidth management is a significant concern that must be addressed during all operations. While bandwidth capabilities are increasing through the use of data compression algorithms, secure and unsecure military and commercial satellite systems, and new technologies, there remains a finite amount of bandwidth at any given time. This limitation can impact not only mission effectiveness but also the number of platforms that



can operate in a given area. To help minimize bandwidth usage, autonomous operations will be conducted to the maximum extent possible with only basic aircraft status information (e.g. systems condition and position) being transmitted to the GCS during noncritical phases of flight. Direct line of sight data transmission to end users and relays through other net-centric platforms will also minimize satellite bandwidth usage.

6.3.2. Net-Centric Operations: Net-Centric Operations involve the sharing of information to improve situational awareness through the networking of compatible systems. This capability can in turn lead to enhanced coordination and unity of effort. The MQ-A's ability to share sensor information such as live video, targeting information and side scan radar hits with other aircraft and ground stations makes the MQ-A system an important component of theater net-centric operations. This capability decreases the need for duplicate systems on other platforms while improving overall mission effectiveness of the joint force. However, as the sharing of information is essential to successful operations, data distribution to non-essential personnel can decrease network performance and lead to information overload resulting in decreased mission effectiveness. The EAS commander shall ensure that aircraft system and sensor data is only transmitted to essential personnel and systems.

Net-centric operations, however, are dependent upon the compatibility of other systems, available bandwidth, radio frequencies, and the security of those transmissions. As such, all systems supporting net-centric operations must be maintained and protected to the maximum extent possible.

6.3.3. Lost Link: Satellite systems are susceptible to a number of threats including jamming, spoofing, interference, scintillation, interception, physical attack, direction finding, and other effects. Any of these factors in addition to mechanical failure can

result in lost link with the controlling or monitoring GCS. In addition to signal protection operations, all flights will be launched with either a full flight plan loaded or emergency routing that will be followed in the event of a lost link condition. Due to the aircraft's autonomous capabilities, the former option is preferred. However, during missions that require semi-autonomous operations, a bingo point will be determined which, upon reaching, the mission will be aborted or modified if the communication link with the GCS is lost. In no cases should a lost link condition result in loss of control of the aircraft and/or subsequent system/aircraft loss.

## **Legal**

### 7. Legal:

7.1. General. Disciplinary and *UCMJ* authority will remain with the service member's service component commander.

### **Notes**

1. Department of Defense, *Quadrennial Roles and Missions Review Report*, 38.

2. Air Force Instruction (AFI) 21-101, *Aircraft and Equipment Maintenance Management*, 29 June 2006, 70.

## ***Definitions***

Allocation	The distribution for employment of limited forces and resources among competing requirements. Specific allocations (e.g., air sorties, nuclear weapons, forces, and transportation) are described as allocation of air sorties, nuclear weapons, and so forth.
Autonomous	An RPA is considered autonomous for its ability to make substantial real-time decisions without human involvement or supervision. A system's autonomy is independent of its ability to transmit information to another station for monitoring. Autonomous operations can rely upon preprogrammed waypoints or real-time internal logic determined routing.
Carbon footprint	The total amount of carbon dioxide produced to directly and indirectly support an organization, event, product, or human activity. With respect to deployments, reducing carbon footprints involves less fuel/energy consumption and fewer troops in theater.
Cargo RPA	An RPA capable of transporting materiel to units or individuals.
Class A mishap	The resulting total cost of damages to government and other property in an amount of \$1 million or more; a DOD aircraft is destroyed; or an injury and/or occupational illness results in a fatality or permanent total disability. DODI 6055.7 (3 October 2000).

Class B mishap	The resulting total cost of damage is \$200,000 or more but less than \$1 million. An injury and/or occupational illness results in permanent partial disability (Table E7.T1. of enclosure 7); or when three or more personnel are hospitalized for inpatient care (which, for accident reporting purposes only, does not include just observation and/or diagnostic care) as a result of a single accident. DODI 6055.7 (3 October 2000).
Class C mishap	The resulting total cost of property damage is \$20,000 or more but less than \$200,000; a nonfatal injury that causes any loss of time from work beyond the day or shift on which it occurred; or a nonfatal occupational illness or disability that causes loss of time from work or disability at any time (lost time case). DODI 6055.7 (3 October 2000).
Modularity	The ability of a system's components to be separated and recombined.
Point of effect	A physical location designated by the functional component commander, service component commander, or a subordinate commander to support operations normally within the combat zone.
Point of need	The physical location designated by the JFC as a receiving point for forces or commodities, for subsequent employment, emplacement, or consumption.

Remotely piloted aircraft (RPA)	Previously referred to as unmanned aerial vehicles (UAV). Powered aerial vehicles sustained in flight by aerodynamic lift over most of their flight path and guided without an onboard crew. They may be expendable or recoverable and can fly autonomously and/or be piloted remotely from ground and/or airborne control stations. As of 14 January 2010, the US Air Force will refer to all UAVs as RPAs.
Semi-autonomous	An RPA is considered semi-autonomous when it can operate partially or entirely autonomously but has a ground operator integrated into the control loop. In this case, a ground controller can offer revised direction to the RPA at any point during operation (e.g., authorize ordnance release, alter route of flight, etc.). These commands would typically be high level.
Time sensitive (TS)/mission critical (MC)	<p>US Air Force: TS/MC—Soonest possible, highest priority (i.e., air evacuation, blood plasma, life, or death situations, etc.). An aircraft will be diverted from its current mission to support a time-sensitive mission.</p> <p>US Army: TS—Delivery must be on the date/time required.  MC—The mission will fail if the delivery does not occur.</p>
Unmanned aircraft system (UAS)	A ground station linked with one or more UAVs. In essence, UAS refers to both the unmanned aerial platforms and its support system including ground control stations, equipment, and personnel.

unmanned aerial    See remotely piloted aircraft (RPA).  
vehicle (UAV)

\*Note: Definitions were extracted from an assortment of DOD sources including, but not limited to, the *DOD Dictionary*, the *United States Air Force Unmanned Aircraft Systems Flight Plan 2009–2047*, 18 May 2009, and the *Department of Defense Quadrennial Roles and Mission Review Report*, January 2009.

## ***Abbreviations***

A/DACG	arrival/departure airfield control group
AAA	antiaircraft artillery
ACO	airspace control order
ADCON	administrative control
AF	Air Force
AFGLSC	Air Force Global Logistics Support Center
AFSAS	Air Force Safety Automated System
AMC	Air Mobility Command
AMD	Air Mobility Division
AMR	air mission request
AO	area of operations
AOR	area of responsibility
ARTCC	Air Route Traffic Control Center
AT	aerial target
ATCC	air traffic control center
ATO	air tasking order
ATOC	air terminal operations center
Auto-GCAS	automatic ground collision avoidance system
CAB	combat air brigade
CAOC	combined air operations center
CAP	combat air patrol
CASCOM	Combined Arms Support Command
CBRNE	chemical, biological, radiological, nuclear, and high-yield explosives
CCTD	CarterCopter Technology Demonstrator
CFACC	combined force air component commander
CLB	combat logistics battalion
CLS	contracted logistical support
CO	commanding officer
CONEMP	concept of employment
CONEX	container express
CSAR	combat search and rescue
DA	Department of the Army
DDOC	Deployment and Distribution Operations Center
DIRCM	directional infrared countermeasures
DIRMOBFOR	Director of Mobility Forces
DOD	Department of Defense



DODI	Department of Defense Instruction
DOTMLPF	doctrine, organization, training, materiel, leader development and education, personnel, and facilities
DRA	Defense Research Associates
DZ	drop zone
EAS	expeditionary airlift squadron
EW	electronic warfare
FARPS	forward arming and refueling points
FMS	flight management system
FOB	forward operating base
FOD	foreign object damage
GAO	Government Accountability Office
GCS	ground control station
GDSS	Global Decision Support System
GPS/INS	global positioning system/inertial navigation system
ICAO	International Civil Aviation Organization
ICS	interim contractor support
IED	improvised explosive device
ISO	International Organization for Standardization
ISR	intelligence, surveillance, reconnaissance
JA/ATT	joint airborne/air transportability training
JALIS-NG	Joint Air Logistics Information System-Next Generation
JFC	joint force commander
JPADS	joint precision airdrop system
km	kilometer
kts	knots
lb.	pound
LCLA	low cost, low altitude
LNO	liaison officer
LZ	landing zone
MAF	Mobility Air Forces
MC	mission critical
MCE	mission control elements
MCT	movement control team
MEL	minimum equipment list

MICAP	mission capable
MOA	memorandum of agreement
MOAB	massive ordnance air blast
MOOTW	military operations other than war
MOU	memorandum of understanding
mph	miles per hour
MQ-A	unmanned or remotely piloted tactical air-lift platform
MRSP	Mobility Readiness Spares Package
NAS	national airspace system
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
ONR	Office of Naval Research
OPCON	Operational Control
PDA	personal digital assistant
RFI	request for information
RPA	remotely piloted aircraft
SAM	surface-to-air missile
SATCOM	satellite communications
SBSS	Standard Base Supply System
STOL	short takeoff and landing
TACON	tactical control
TCAS	traffic collision avoidance system
TS	time sensitive
UAS	unmanned aircraft system
UAV	unmanned aerial vehicle
UCARS	UAV Common Automatic Recovery System
UCAV	uninhabited combat aerial vehicles
UHF	ultra-high frequency
VTOL	vertical takeoff and landing



## ***Bibliography***

- Absolute Astronomy. "Tail Rotor." [http://www.absoluteastronomy.com/topics/Tail\\_rotor](http://www.absoluteastronomy.com/topics/Tail_rotor) (accessed 20 January 2010).
- Aerospace Web. "Fenestron Tail Rotor." <http://www.aerospacweb.org/question/helicopters/q0212a.shtml> (accessed 20 January 2010).
- Air Force Instruction (AFI) 21-101. *Aircraft and Equipment Maintenance Management*, 29 June 2006.
- Air Force News*. "EADS and DRS to Develop Helicopter Obstacle Warning Systems," 26 June 2007. <http://www.defencetalk.com/eads-and-drs-to-develop-helicopter-obstacle-warning-systems-12624/> (accessed 10 February 2010).
- Air Force Safety Automated System (AFSAS). Class A, B, and C mishap data extracted on 14 December 2009, 13 January 2010, and 20 January 2010.
- Air Mobility Command (AMC). *Air Mobility Master Plan 2010*. Scott AFB, IL, October 2009.
- AMC Specialized Contracting Branch. "Solicitation Number: RFI\_for\_Unmanned\_Cargo\_Aircraft," 28 September 2009. [https://www.fbo.gov/index?s=opportunity&mode=form&id=0f759204d5a607bdce9a528a5bd63720&tab=core&\\_cview=0](https://www.fbo.gov/index?s=opportunity&mode=form&id=0f759204d5a607bdce9a528a5bd63720&tab=core&_cview=0) (accessed 25 February 2009).
- Anderson, Donald. *OEF, COPs, and Bases.xlsx*, AMC/A9, 14 January 2010.
- Army Combat Readiness/Safety Center. *Class A, B, and C Mishap Data*.
- Aviation Week & Space Technology*. "2009 World Military Aircraft Inventory: United States." *Aviation Week*, 26 January 2009. [http://www.aviationweek.com/aw/sourcebook/content.jsp?channelName=pro&story=xml/sourcebook\\_xml/2009/01/26/AW\\_01\\_26\\_2009\\_p0240-112924-158.xml&headline=WorldMilitaryAircraftInventory-United+States](http://www.aviationweek.com/aw/sourcebook/content.jsp?channelName=pro&story=xml/sourcebook_xml/2009/01/26/AW_01_26_2009_p0240-112924-158.xml&headline=WorldMilitaryAircraftInventory-United+States) (accessed 6 December 2009).
- Bell Boeing. *V-22 Osprey Pocket Guide*. Amarillo, TX: Bell Boeing V-22 Program Office, 2007.
- Bell Helicopter. *Eagle Eye Pocket Guide*. Fort Worth, TX: Bell Helicopter Textron, June 2005.

- Benney, Richard, Mike Henry, Kristen Lafond, Andrew Meloni, LCDR Gregory Cook, Sanjay Patel, and Larry Goodell. "Joint Medical Distance Support and Evaluation (JMDSE) Joint Capability Technology Demonstration (JCTD) & Joint Precision Air Delivery Systems (JPADS)." SOFIC 2009 Paper No. 8304. <http://www.nps.edu/Academics/Centers/ADSC/papers/JPADS%20-%20Benney%20-%20JMDSE,%20JCTD%20and%20JPADS.pdf>.
- Bilstein, Roger E. *Airlift and Airborne Operations in World War II: The US Army Air Forces in World War II*. Air Force History and Museums Program, 1998. [http://www.airforcehistory.hq.af.mil/Publications/fulltext/airlift\\_&\\_airborne\\_ops\\_wwii.pdf](http://www.airforcehistory.hq.af.mil/Publications/fulltext/airlift_&_airborne_ops_wwii.pdf) (accessed 5 December 2009).
- Boeing. "AFRL, Boeing Demonstrate That UAVs Can Perform Automated Aerial Refueling." [http://www.boeing.com/news/releases/2007/q4/071204a\\_nr.html](http://www.boeing.com/news/releases/2007/q4/071204a_nr.html) (accessed 11 February 2010).
- Buxbaum, Peter. "Technological Advances Have Brought Precision to the Delivery of Airdropped Supplies." *Special Operations Technology*. <http://www.special-operations-technology.com/sotech-archives/193-sotech-2009-volume-7-issue-6/1858-on-the-mark.html> (accessed 6 December 2009).
- Carter, Jay Jr. *The CHT Slowed-Rotor/Compound Aircraft: Candidate for AMT*. Wichita Falls, TX: Carter Aviation Technologies (Carter). <http://www.vtol.org/pdf/stov-60.pdf> (accessed 23 February 2010).
- Central Intelligence Agency. "Afghanistan." *World Factbook*. <https://www.cia.gov/library/publications/the-world-factbook/geos/af.html> (accessed 12 December 2009).
- Dao, James. "The Costs of Enduring Freedom." *New York Times*, 18 November 2001. <http://www.nytimes.com/2001/11/18/weekinreview/the-costs-of-enduring-freedom.html> (accessed 11 February 2010).
- Deets, Dwain A., and Dana Purifoy. *Operational Concepts for Uninhabited Tactical Aircraft*. Edwards Air Force Base, CA: NASA Dryden Flight Research Center, 1998.
- Defense Oversight Council Aviation Safety Improvements Task Force Safety Technology Working Group. *Fighter/*

- Attack Automatic Collision Avoidance Systems Business Case*, 24 May 2006.
- Defense Research Associates, Inc. "Sense and Avoid." <https://www.dra-inc.net/n/sense.php> (accessed 11 February 2010).
- Defense Science Board Task Force on UAVs and UCAVs. *Unmanned Aerial Vehicles and Uninhabited Combat Aerial Vehicles*. Washington, DC: Defense Science Board, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, February 2004. <http://www.iwar.org.uk/rma/resources/dsb/uav.pdf> (accessed 12 January 2010).
- Department of Defense. *DOD Dictionary of Military Terms*. [http://www.dtic.mil/doctrine/dod\\_dictionary/](http://www.dtic.mil/doctrine/dod_dictionary/).
- . *Quadrennial Roles and Missions Review Report*, January 2009. [http://www.defense.gov/news/Jan2009/QRMFinalReport\\_v26Jan.pdf](http://www.defense.gov/news/Jan2009/QRMFinalReport_v26Jan.pdf) (accessed 22 January 2010).
- Department of Defense Instruction (DODI) 6055.7. *Accident Investigation, Reporting, and Record Keeping*, 3 October 2000.
- Dyche, Maj David D. *Military Reorganization: Challenge and Opportunity*, 1990. <http://www.globalsecurity.org/military/library/report/1990/DDD.htm> (accessed 05 April 2010).
- 801st Brigade Support Battalion. "Lessons Learned," CASCOM, DL2/QA, R-CAAT Series 801st Brigade Support Battalion Lessons Learned Presentation Transcript.
- Fellows, Lt Col James A., LCDR Michael H. Harner, Maj Jennifer L. Pickett, and Maj Michael F. Welch. *Airlift 2025: The First with the Most*. August 1996. <http://csat.au.af.mil/2025/volume2/vol2ch04.pdf> (accessed 21 October 2009).
- General Accountability Office. *Presidential Travel: DOD Airlift Cost for White House Foreign Travel*, GAO/NSIAD-00-209, August 2000.
- GlobalSecurity.org. "MQ-1B Armed Predator UAV." <http://www.globalsecurity.org/intell/systems/armed-predator.htm> (accessed 13 January 2010).
- . "Stopped-Rotor Aircraft." <http://www.globalsecurity.org/military/systems/aircraft/stopped-rotor.htm> (accessed 17 January 2010).

- Hayes, Lt Col Mike. "MAF/SOF/Helo Assignments." Briefing. Air Force Personnel Center, Randolph AFB, TX, 10 December 2009.
- Headquarters Air Force Flight Standards Agency. *A3A-10-01-Unmanned Aircraft System (UAS) Terminology Clarification*, 14 January 2010.
- Helis.com. *Bell Eagle Eye Completes Auto and Tests at Yuma Proving Grounds as Part of the Navy's VTOL Demonstration Program*. 17 May 2000. <http://www.helis.com/news/2000/beagleeye.htm> (accessed 22 September 2009).
- Horton, Timothy W., and Robert W. Kempel. *Flight Test Experience and Controlled Impact of a Remotely Piloted Jet Transport Aircraft*. NASA Technical Memorandum 4084, NASA Ames Research Center, Dryden Flight Research Facility, Edwards AFB, CA. November 1988. [http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19890006539\\_1989006539.pdf](http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19890006539_1989006539.pdf) (accessed 11 February 2010).
- iCasualties.org. "Operation Enduring Freedom: US Fatalities." <http://icasualties.org/OEF/Nationality.aspx?hndQry=US> (accessed 10 December 2009).
- Jernigan, Lt Col Mike, USMC, company officer of Combat Logistics Battalion-3, 3d Marine Logistics Group, Afghanistan 2008-2009. To the author. E-mail, 10 December 2009. E-mail included the attachment, "Typical Afghanistan CLP Breakdown."
- Kauchak, Marty. "New Joint and Service Solutions Bolster Personnel and Cargo Airdrop Capabilities." *Special Operations Technology* 4, is. 6, (17 June 2009). <http://www.special-operations-technology.com/sotech-archives/169-sotech-2008-volume-4-issue-6/1534-a-eye-on-the-impact-point.html> (accessed 6 December 2009).
- Kelly, B. "Air Force Total Aircraft Inventory: FY 1996 and Prior." *Federation of American Scientists*. AF/XPPE. <http://www.fas.org/man/dod-101/usaf/docs/tai-fy96.htm> (accessed 3 December 2009).
- Lichte, Gen Arthur J. "Commander's Intent." *Air Mobility Master Plan: 2010*. Scott AFB, IL, October 2009.
- McDaid, Hugh, and David Oliver. *Smart Weapons: Top Secret History of Remote Controlled Airborne Weapons*. New York: Welcome Rain, 1997.

- Manske, Lt Col Chad T. *Unmanned Airlift: A Viable Option for Meeting the Strategic Airlift Shortfall*. Maxwell AFB, AL: Air University Press, September 2004.
- Mapes, Col Pete. Briefing. Air Force Research Laboratory. Subject: Auto-GCAS, May 2006.
- Melnyk, Mike. Briefing presented by Northrop Grumman at the AMC Unmanned Intratheater Airlift Conference at Scott AFB, IL, 17 November 2009. Subject: "AMC Industry Day: Autonomous VTOL UAV MUVr."
- Mitchell Industries. *Final Proposal: Feasibility of Modular Unmanned Logistics Express: IPT 3*, 27 April 1998. [http://rocket.itsc.uah.edu/u/education/files/IPT\\_Pub/files/1998/IPT1998\\_Phase3\\_Final\\_Report\\_Team3\\_Final.pdf](http://rocket.itsc.uah.edu/u/education/files/IPT_Pub/files/1998/IPT1998_Phase3_Final_Report_Team3_Final.pdf) (accessed 14 October 2009).
- Natick Soldier Research. Development and Engineering Center—United States Army Research Development and Engineering Command. *Precision Airdrop Technology Conference and Demonstration 2007: PATCAD 2007 Final Report*, 10 February 2008. <http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA488396&Location=U2&doc=GetTRDoc.pdf> (accessed 6 December 2009).
- National Aeronautics Space Administration. "Wallops Flight Facility Goddard Space Flight Center Flight Summaries for FY08." <http://sites.wff.nasa.gov/code820/summaries/FY08.html> (accessed 5 April 2010).
- Naval-Technology.com. "Fire Scout VTUAV Unmanned Aerial Vehicle, USA." <http://www.naval-technology.com/projects/firescout/> (accessed 20 February 2010).
- Northrop Grumman. "MQ-8B Navy Fire Scout." [http://www.as.northropgrumman.com/products/mq8bfirescout\\_navy/index.html](http://www.as.northropgrumman.com/products/mq8bfirescout_navy/index.html) (accessed 20 February 2010).
- NOVA. "Time Line of UAVs." <http://www.pbs.org/wgbh/nova/spiesfly/uavs.html> (accessed 20 January 2010).
- O'Hanlon, Michael E., and Jason H. Campbell. *Iraq Index: Tracking Variables of Reconstruction & Security in Post-Saddam Iraq*. Brookings Institute, 1 October 2007. <http://www.brookings.edu/fp/saban/iraq/index.pdf> (accessed 8 December 2009).
- 101st Sustainment Brigade. "Lessons Learned," CASCOM, DL2/QA, R-CAAT Series 101st Sustainment Brigade Lessons Learned Presentation, 6 May 2009.



- Rupar, M., J. Doffoh, and R. Mereish. "High Altitude Relay and Router." *2007 NRL Review*, 165–67. [http://www.nrl.navy.mil/content\\_images/07Information\(Rupar\).pdf](http://www.nrl.navy.mil/content_images/07Information(Rupar).pdf) (accessed 5 April 2010).
- STRATFOR. "US, Afghanistan: A New Class of Unmanned Aerial Vehicles." [http://www.stratfor.com/memberships/142813/analysis/20090723\\_u\\_s\\_afghanistan\\_new\\_class\\_unmanned\\_aerial\\_vehicles](http://www.stratfor.com/memberships/142813/analysis/20090723_u_s_afghanistan_new_class_unmanned_aerial_vehicles) (accessed 23 February 2010).
- Stratford, Jim. "Northrop Grumman Advanced Information Architecture Concepts Highlighted in Joint Demonstration with US Marine Corps." Northrop Grumman Integrated Systems, 13 December 2005. [http://www.irconnect.com/noc/press/pages/news\\_printer.html?d=91138&print=1](http://www.irconnect.com/noc/press/pages/news_printer.html?d=91138&print=1) (accessed 13 January 2010).
- Taylor, A. J. P. *Jane's Book of Remotely Piloted Vehicles*, 1977.
- Terdiman, Daniel. "NASA Tests Super-High-Altitude Balloon." cnet, 8 January 2009. [http://news.cnet.com/8301-13772\\_3-10137183-52.html](http://news.cnet.com/8301-13772_3-10137183-52.html) (accessed 5 April 2010).
- US Air Force. "C-17 Fact Sheet." <http://www.af.mil/information/factsheets/factsheet.asp?id=86> (accessed 11 February 2010).
- . *Unmanned Aircraft Systems Flight Plan 2009–2047*. Washington, DC: Headquarters United States Air Force, 18 May 2009.
- US Army Aviation Center of Excellence Concepts and Requirements Directorate. "Joint Multirole Aircraft Platform Industry Presentation."
- US Army Combined Arms Support Command. *Logistics Resupply Role of Unmanned Aircraft Systems (UAS) Concept of Employment/DOTMLPF Analysis*, 25 February 2008.
- US Army Safety Center. *Class A, B, and C Mishap Data for the Period of September 2001–December 2009*. Provided 16 February 2010.
- US Government Accountability Office. *Defense Acquisitions: Strategic Airlift Gap Has Been Addressed, but Tactical Airlift Plans Are Evolving as Key Issues Have Not Been Resolved*. Report to the Subcommittee on Air and Land Forces, Committee on Armed Services, House of Representatives, GAO-10-67, November 2009. <http://>

- [www.gao.gov/new.items/d1067.pdf](http://www.gao.gov/new.items/d1067.pdf) (accessed 5 December 2009).
- . *Defense Acquisitions: Strategic Airlift Gap Has Been Addressed, but Tactical Airlift Plans Are Evolving as Key Issues Have Not Been Resolved*. Summary of Report to the Subcommittee on Air and Land Forces, Committee on Armed Services, House of Representatives, GAO-10-67, November 2009. <http://www.gao.gov/products/GAO-10-67> (accessed 5 December 2009).
- US House of Representatives. *John Warner National Defense Authorization Act for Fiscal Year 2007*, 109th Cong., 2nd sess., 2007, H. R. 5122, 282. [http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109\\_cong\\_bills&docid=f:h5122enr.txt.pdf](http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109_cong_bills&docid=f:h5122enr.txt.pdf) (accessed 27 January 2010).
- US Marine Corps. “CH-46 Fact Sheet.” <http://hqinet001.hqmc.usmc.mil/AVN/documents/aircraft/rotarywing/ch46.htm> (accessed 11 December 2009).
- . “CH-53 Fact Sheet.” <http://hqinet001.hqmc.usmc.mil/AVN/documents/aircraft/rotarywing/ch53.htm> (accessed 11 December 2009).
- . “KC-130 Fact Sheet.” <http://hqinet001.hqmc.usmc.mil/AVN/documents/aircraft/fixedwing/kc130.htm> (accessed 11 December 2009).
- . “Solicitation Number: M6785409R9015,” 28 January 2009. [https://www.fbo.gov/index?s=opportunity&mode=form&id=87c081f0c38b5a1bf6bea130535614bf&tab=core&\\_cview=1](https://www.fbo.gov/index?s=opportunity&mode=form&id=87c081f0c38b5a1bf6bea130535614bf&tab=core&_cview=1) (accessed 4 February 2010).
- . “UH-1 Fact Sheet.” <http://hqinet001.hqmc.usmc.mil/AVN/documents/aircraft/rotarywing/uh1.htm> (accessed 11 December 2009).
- . *Universal Needs Statement (UNS) for the Cargo Unmanned Aircraft System (Cargo UAS)*, 27 August 2008.
- . “V-22 Osprey.” <http://www.marines.mil/unit/aviation/Pages/tiltrotor.aspx> (accessed 11 December 2009).
- US Naval Safety Center. *Class A Mishap Data for the Period of 1998–2008*. Provided 12 January 2010.
- US Navy. “United States Navy Fact File: CH-53D Sea Stallion Helicopter.” [http://www.navy.mil/navydata/fact\\_display.asp?cid=1200&tid=200&ct=1](http://www.navy.mil/navydata/fact_display.asp?cid=1200&tid=200&ct=1) (accessed 11 December 2009).

- US Senate. Committee on Armed Services. *National Defense Authorization Act for Fiscal Year 2006*, 17 May 2005. [http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109\\_cong\\_reports&docid=f:sr069.109.pdf](http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109_cong_reports&docid=f:sr069.109.pdf) (accessed 20 January 2010).
- US Training Command Joint Distribution Process Analysis Center. "Request for Information: Future Deployment and Distribution Assessment." NAICS Code: 541990.
- Vice Chief of Staff Army/Vice Chief of Staff Air Force. *USAF Direct Support of USA Time-Sensitive/Mission Critical Mission Concept of Employment*, 23 September 2009.
- Vogelaar, Rob. "Boeing A160T Unmanned Helicopter Flies with Foliage-Penetrating Radar in DARPA Tests." *AviationNews.eu*, 13 October 2009. <http://www.aviationnews.eu/2009/10/13/boeing-a160t-unmanned-helicopter-flies-with-foliage-penetrating-radar-in-darpa-tests/> (accessed 27 January 2010).
- WBB Consulting. "Concept of Employment (COE)." <http://www.wbbinc.com/concept-employment.html> (accessed 12 January 2010).
- . "CONOPS Concept of Operations." <http://www.wbbinc.com/conops-concept-of-operations.html> (accessed 12 January 2010).